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SPRING WHEAT IN THE GREAT PLAINS AREA:

RELATION OF CULTURAL METHODS TO PRODUCTION.

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INTRODUCTION.

This bulletin contains a study of the yields of spring wheat obtained under various methods of seed-bed preparation at 14 stations in the Great Plains region. The area considered in these

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The following-named men have held positions on the scientific staff of the Office of Dry-land Agriculture during the past nine years, but have resigned or have been transferred to other offices of the Department of Agriculture: Sylvester Balz, F. L. Kennard, J. E. Payne, L. E. Hazen, C. A. Jensen, H. R. Reed, W. O. Whitcomb, C. H. Plath, F. Knorr, and R. W. Edwards.

The data here reported from the stations in Kansas, Nebraska, North Dakota, and Montana have been obtained in cooperation with the agricultural experiment stations of the respective States. In South Dakota, Colorado, Texas, Oklahoma, and New Mexico the stations are operated by the United States Department of Agriculture.

Field, office, and laboratory facilities, teams, and implements have been provided by the Office of Western Irrigation Agriculture, at Huntley, Mont., Belle Fourche, S. Dak., and Mitchell, Nebr., and by the Office of Cereal Investigations at Amarillo, Tex., and Archer, Wyo. The Biophysical Laboratory has cooperated in obtaining the meteorological data reported.

NOTE.—This bulletin is intended for all who are interested in the agricultural possibilities of the Great Plains area.

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investigations consists of about 400,000 square miles of territory (fig. 1). It is bounded on the east by the ninety-eighth meridian of longitude, on the west by the foothills of the Rocky Mountains (indicated by the 5,000-foot contour), on the north by the Canadian boundary, and on the south by the thirty-second parallel. The area covers parts of 10 States, and includes all of the stations herein considered except the one at Archer, Wyo.

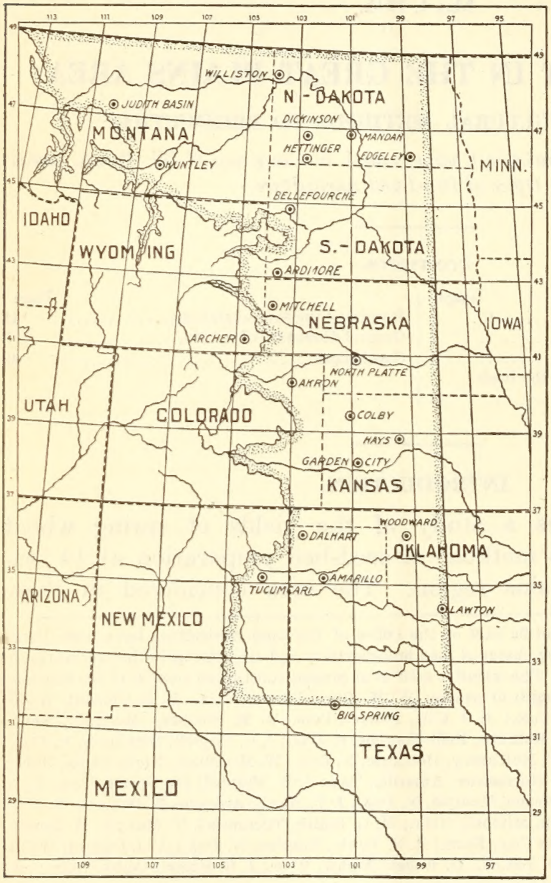

FIG. 1.—Sketch map of the Great Plains area, which includes parts of ten States and consists of about 400,000 square miles of territory. Its western boundary is indicated by the 5,000-foot contour. The location of each field station within the area is shown by a dot within a circle (⊙).

The study as here presented deals only with spring wheat and is made in such a way as to show the effect of cropping and cultivation in only the year preceding its growth. Reference hereafter is made to the crop only as wheat, but it should be borne in mind that spring wheat is meant. The yields of winter wheat and its response to cultural methods are in many cases very different from spring wheat. There is also given a study of the comparative cost of production of wheat under each of the methods studied and the resulting profit or loss.

The work here reported from 14 stations covers an aggregate of 73 station years and embodies the data from a total of 1,683 plat years. By station year is meant one year at one station; by plat year is meant one plat at one station for one year. It is manifestly impossible in dealing with such a mass of data to go into much detail; only some of the broader phases of the evidence are here considered.

Dealing as it does with only one crop, to which certain sections of the Plains are obviously not adapted, this report does not afford a measure of judging the agricultural value or possibilities for other crops of any section of the country.

In 1906 the Office of Dry-land Agriculture of the United States Department of Agriculture began field investigations of the problems in methods of crop production in the Great Plains. The work begun at that time has been constantly and steadily added to, until in 1914 work was conducted at 20 stations. The results here presented are from 14 stations, records covering only one or two years having been excluded.

The method of work adopted was that of raising the standard crops of each section both in rotation and by different methods of preparation under systems of continuous cropping. In no case have rotations requiring more than 6 years been used. Those of even this length have been tried only when sod of tame grass crops are included. More of the work has been done with 3-year and 4-year rotations.

Figure 2 shows a diagram of the plats in the experimental field laid out in 1908 at the Judith Basin Field Station. This station, being a representative one, will serve to illustrate the general scheme and plan of work. The plats here, as in all the work, are one-tenth acre in size. Their dimensions are 2 by 8 rods. Along their larger dimension the plats are separated by bare alleys 4 feet in width. Along the ends of the plats they are separated by roads 20 feet wide. At this station six crops are represented in a series of continuously cropped plats lettered from A to F or G. In this group, plats C and D are alternately cropped and summer tilled, so that each year a crop is grown on land that was summer tilled the previous year and a plat is summer tilled for cropping the next year.

The remainder of the field is in rotations in which each plat is known by a rotation number and letter. On the field diagram the separation of rotations is indicated by heavy lines.

The movement of the crops in the rotation is in the direction from Z to A and from A back to the letter that marks the other end of the rotation.

In figure 2 the diagram is filled out to show the cropping in 1914. The letters following the crop indicate the treatment given the ground in preparation for it, S. P. standing for spring plowed, F. P. for fall plowed, Fal., or S. F., for summer tilled, G. M. for green manured, and D. C. for disked corn land. The addition of the letter M indicates the use of manure. To illustrate: In 1914 plat A of the 4-year rotation No. 14 was in corn on spring-plowed land, plat B was in wheat on disked corn ground, and plat C was in winter rye on fall-plowed land. This would be plowed under for green manure. Plat D was in oats

where winter rye had been turned under the year before. In 1915 A will be in wheat, B in winter rye, C in oats, and D in corn.

In the present stage of development of the work, the effect of the immediately preceding crop and of the method of handling its stubble in preparing the seed bed greatly overshadows the effects of the rotations considered as units. Some of the rotations are calculated to conserve or to accumulate fertility and organic matter in the soil, while others may perhaps deplete it, but on the naturally fertile soils of the Plains such results are not strongly evidenced in the first years of treatment. The controllable factors that exert the greatest influence on production are water supply, physical condition of the seed bed, and a recognized if not understood effect of the immediately preceding crop. The crop of a single year brings the land back so near to uni-

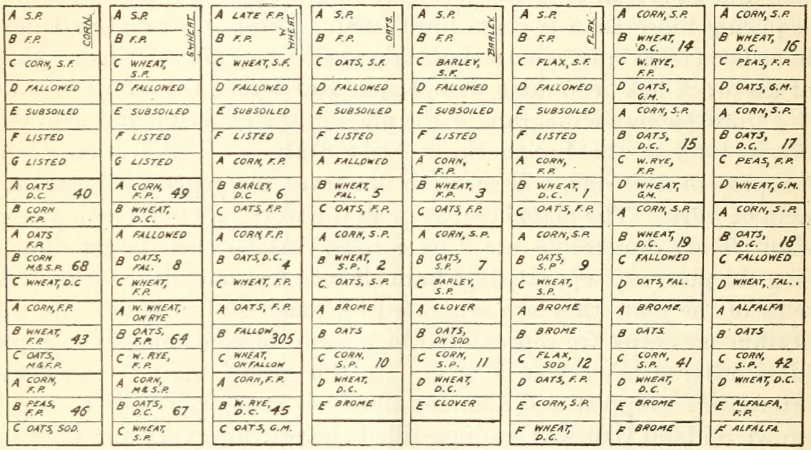

FIG. 2.—Diagram of the dry-land rotation field at the Judith Basin Field Station. The lettering shows the cropping practiced in 1914. The explanation of abbreviations used is as follows: D. C. = disked (corn land), Fal., or S. F.=summer tilled, F. P.=fall plowed, G. M.=green manured, M.=manured, S. P.= spring plowed.

formity in these factors that their probable residual effect is not great enough in the work in hand to introduce serious error into a study as here made.

It seems advisable at the present time to prepare a series of bulletins discussing in each the results secured with one crop, as determined by the treatment of the land in only the one year preceding its growth.

CLIMATIC CONDITIONS.

The annual precipitation at the various stations varies from about 15 to 21 inches. The average increases from north to south and from west to east. An increase in the average daily evaporation from north to south prevails. The rainfall is fluctuating in character. Years of heavy rainfall may follow years when it is deficient, and vice versa.

Or a succession of years may be either comparatively wet or comparatively dry.

The seasons of light rainfall are usually accompanied by other unfavorable conditions, such as higher wind velocity, higher temperature, and lower humidity. The distribution of the rainfall is also very important in its influence on crop production. A crop may be produced on a relatively small seasonal rainfall if it is well distributed. On the other hand, a season of higher rainfall, because of unfavorable distribution, may result in crop failure.

Space in this bulletin will not permit the presentation of a complete record of the climatic conditions at the various stations during the time the work here reported was being done. It is, however, available in publications of the United States Weather Bureau. Table I gives the lowest, highest, and average annual and seasonal precipitation for the time covered by the work. The seasonal evaporation is also shown. By seasonal is meant the precipitation or evaporation for the period between the average time of seeding and the average time of harvesting. No attempt is made to show other climatic factors, all of which are important.

TABLE I.—*Annual and seasonal precipitation and seasonal evaporation at fourteen stations in the Great Plains area.*[1]

Station.	Altitude[2] (feet).	Precipitation[3] (inches).						Seasonal evaporation[3] (inches).		
		Annual.			Seasonal.					
		Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
Judith Basin	4,228	14.96	23.78	18.06	6.50	10.90	8.62	19.117	26.273	21.330
Huntley	3,000	11.92	11.92	11.92	5.00	7.35	6.18	19.820	20.594	20.207
Williston	1,875	10.28	18.99	14.84	5.62	12.00	8.31	21.104	28.269	24.705
Dickinson	2,543	11.93	21.22	16.69	5.31	16.27	10.06	18.379	27.366	22.377
Edgeley	1,468	11.94	21.95	16.71	5.08	15.73	9.60	17.664	25.362	20.657
Hettinger	2,253	12.72	15.68	14.20	8.82	12.89	10.69	20.111	24.248	22.430
Belle Fourche	2,950	6.64	17.73	13.11	1.92	12.75	6.82	23.627	33.906	27.220
Scottsbluff	3,950	13.77	18.51	16.14	5.56	8.26	7.11	24.698	26.647	25.718
North Platte	3,000	11.18	23.01	18.05	4.38	11.25	7.77	25.954	35.255	30.253
Akron	4,600	14.51	22.46	18.28	5.32	9.52	7.82	25.917	32.691	28.781
Hays	2,050	15.59	27.80	21.30	3.87	12.87	9.55	29.390	41.317	32.628
Garden City	2,900	11.82	23.58	18.54	5.01	8.16	6.85	33.315	38.926	35.332
Dalhart	4,000	13.69	16.35	15.11	4.54	14.86	8.17	33.381	41.002	38.596
Amarillo	3,676	10.69	27.80	18.28	5.03	11.49	7.05	32.305	40.704	36.709

[1] The years covered are the same as for the data shown in the other tables for each station.

[2] The altitude given is for the field where the work was done and is based in most cases on that of the nearest town.

[3] The record of annual precipitation for 1914 is not included. The records of seasonal precipitation and evaporation for 1914 are included for all stations, the evaporation being figured from Apr. 1 to July 31. The seasonal rainfall is the amount from Apr. 1 to July 31 for stations north of and including that at Belle Fourche. For stations south of Belle Fourche it is the amount between Mar. 1 and June 30. Evaporation measurements are made from a free water surface in a tank sunk into the soil to almost its full depth. The water surface is kept about level with the surface of the ground.

GENERAL PLAN OF THE INVESTIGATIONS.

Durum wheat has been used in these trials. The aim has been to use at each station the best standard variety available for general use. Changes are made only when necessitated by loss of seed or when

varietal tests, breeding, or seed selection makes available for general use a better variety. The same seed is used on all plats at any one station in any particular year.

All seeding is done with a drill. Drill rows are spaced from 6 to 8 inches. As compared with more humid sections, light seeding is practiced. The rate varies from 2 to 4 pecks, depending upon the location and the consequent average climatic conditions. At Edgeley, N. Dak., where summer rains are more frequent and weeds more troublesome, the seeding rate is 6 pecks per acre. Generally speaking, the drier the condition the lighter the seeding. The seeding rate, date, and manner of seeding are the same for all plats at the same station in any one year.

For comparative study of the effect of environment and for securing data on production certain of the work is made uniform at all stations. This results in the attempted growth of spring wheat and other crops in sections to which they are not adapted and in their growth at certain stations by methods not adapted to the conditions obtaining there. Such work, however, is limited, the most intensive studies at each station being undertaken on the crops which are of greatest promise in that locality.

In the present study a table is presented for each station. The first part of such table shows the yields that have been obtained in each year by each of the different methods under which wheat has been grown, considering only the treatment during the one year immediately preceding the crop. The reasons for not differentiating the study further have already been stated.

Where more than one plat has been grown under the same treatment for the previous year, only the average yield of the whole number of plats so grown is given. Column 2 of the table shows the number of plats so averaged. In the presentation of yields, the column headed "Treatment and previous crop" indicates the method of preparation, whether fall plowed, spring plowed, listed, subsoiled, disked, green manured, or summer tilled. Some of these are again subdivided to show the previous crop. To illustrate: The table for Judith Basin (Table V) shows that there were five plats of wheat each year grown on fall-plowed land. On two of these the wheat followed corn, on two it followed oats, and on one it followed wheat. The average yield on fall plowing as given is the average of the five plats, not the average of the given averages. To obtain these averages it is necessary to use the figures as many times as there were plats averaged in obtaining them. The succeeding columns need no explanation, as they are the yields for each year as indicated and the average of each method for the whole period of years. In the last column, where the average appears under the heading "Average,"

the calculation is from the left. For a rough comparison of seasons, the bottom line of the first half of the table gives an average of all plats for each year, the average of the yearly average yields appearing in the last column to the right.

Throughout the tables, where wheat is shown as following corn on either fall or spring plowing, it is in a 3-year rotation in which the other crop is oats. Where wheat is shown as following oats on fall or spring plowing, it is in a 3-year rotation where in the third year the land is either cropped to corn or is summer tilled. Where wheat follows wheat under any treatment it is in a system of continuous cropping to wheat by the method indicated.

The methods of operation have been similar at all stations. Fall plowing is done early, except after crops like corn that are not removed from the ground early. It is done to a good depth, the standard being set at 8 inches. Ground may be either worked down or left rough over winter. Spring-plowed land may be disked in the fall or may be undisturbed until spring, when plowing is done just before seeding. Plowing is done to a good depth, usually at about 8 inches. This applies to all wheat plats except one plat at each station on which wheat follows wheat. The stubble of this plat is undisturbed until spring, when it is plowed shallow (at about 4 inches) and is then given a minimum of cultivation, which usually consists of one or two harrowings. In those cases where an additional plat appears under spring plowing after wheat, it is plowed deep instead of shallow.

Under the subhead "Listed" there is shown at some stations the yield from one plat continuously cropped to wheat. Instead of plowing this plat, it is furrowed out with a lister at the time of fall plowing. It is cultivated down level by seeding time.

Under the subhead "Subsoiled" there is shown at the stations where it has been tried the results from a plat continuously cropped to wheat. At the time of plowing, a subsoil plow is run in the bottom of the furrow, usually loosening the soil to a total depth of about 14 inches. The variation from this depth is hardly more than 2 inches either way. In general, subsoiling has been done two years in succession and then omitted for two years.

Under the subhead "Disked" is given the average of a considerable number of plats of wheat following corn. These occur in alternate cropping to wheat and corn, in 3-year rotations in which the other crop is oats, and in 4-year rotations in which the other crops are summer tillage and oats or barley. In sod rotations, wheat on disked corn ground is the third crop after breaking the sod. At some stations are shown additional plats on disked ground following potatoes and following sorghum. These are in 4-year rotations.

Under the subhead "Green manured" are given the yields of wheat following the plowing under of rye, peas, or sweet clover, as specified. This treatment is in 4-year rotations in which one of the other crops is corn and the other is one of small grain.

At each station several plats of spring wheat are grown on summer-tilled land. One of these is from land alternately summer tilled and cropped to wheat; one is from a 3-year rotation of summer tillage, wheat, and oats; and others are from 4-year rotations in which the other crops are corn or potatoes and oats or barley.

The method of summer tillage practiced has been of the intensive type. The ground is fall plowed and clean cultivation is continued through the next year and until the wheat is seeded in the second spring. In some cases it is necessary in order to destroy weeds to replow during the summer when the land is fallow. At other stations summer-tilled plats are plowed but once. Experiments not here reported are under way to ascertain the best method of fallowing. Indications are that equally good results can be obtained with a less intensive method than has been practiced in the investigations here reported.

The yields given in these tables begin with the second year of crop production at each station. All crops are produced the first year on land uniform in its treatment. In some cases an entire crop has been lost by hail. These years are not considered in computing averages, as the crops resulting from all methods alike were destroyed.

By the use of the basic data which follows in Tables II, III, and IV there has been compiled a second part embodying a summarized statement of the table of yields for each station. In this summary are brought together in different form the yields in the first part of such table. The value of the average yields thus obtained is shown together with the cost of production (as computed from the available data). In the last line of the table is given the average profit or loss resulting from the production of wheat by the method shown at the head of the column. Loss is indicated by the minus sign.

COMPARISON OF CULTURAL METHODS ON THE BASIS OF COST.

In order to make a comparison of the relative profits or losses of the several cultural methods, as shown in the second part of the table for each station, it was necessary to establish the average cost of production under each of these methods. The methods under study vary a great deal in the labor involved and in the consequent cost of preparation. Table IV has therefore been compiled in order to show the average cost of the methods under study as determined from the data of eight of the stations having the most trustworthy records. An average of the records for 5½ years at each station has

been used in compiling this table. This is equivalent to a record of 44 years at one station. An accurate record has been kept of all the farm operations performed under the various methods under trial. These have been averaged for the eight stations. The amount of work required for some methods of treatment varies with the season and with the soil, and the expense of some operations varies with the soil. The amount of labor performed under each of the methods was neither more nor less than that which the man in charge believed to be necessary to bring about the results sought.

In computing the cost of the various operations a fixed wage of $2 per day for a man and $1 a day for a horse was adopted. This may be above or below the actual labor cost in any particular locality, but it is believed to be a fair average and one that will afford a profitable market to the farmer for his labor. The time required for men and teams to cover a given acreage in each of the several farm operations obviously varies with soils and other conditions. The average shown in Table II has been determined from the actual experience of a large number of men connected with these investigations, which experience has extended over a wide range of conditions and many years of time.

The factors included in the cost of production are calculated on an acre basis for each of the separate operations performed, beginning with the preparation of the land and ending with the harvesting and shocking of the grain. To these items are added the cost of seed at 85 cents per acre, interest and taxes on the land investment, calculated at 8 per cent on a valuation of $20 per acre, and the deterioration and repairs of the binder at 15 cents per acre. No allowance is made for deterioration of other farm equipment, as it is believed that the wages allowed for men and teams are sufficient to cover this item for the remainder of the equipment. The above-mentioned items are fixed charges per acre; that is, they do not vary greatly with the yield per acre, except the item of twine, but this variation is not sufficient to materially affect the relative total cost of production under the several methods.

Table II shows the cost per acre based upon what is considered an average day's work for each of the farm operations involved at the above-mentioned wage. As before stated, the type of soil and seasonal conditions will determine to a certain extent the labor required and the consequent cost per acre. The cost of production as computed in Tables II and IV is not offered as being absolute for any locality, either in the amount of labor required or its cost, but is given as a working basis for the comparison of the results by different methods of preparation.

TABLE II.—*Average cost per acre* [1] *of the farm operations involved in growing spring wheat in the Great Plains area.*

[The wage scale assumed is $2 per day for each man and $1 per day for each horse.]

Operation.	Force employed.		Day's work.	Item cost.	Cost per acre.
	Men.	Horses.			
			Acres.		
Plowing	1	4	3½	.....	$1.71
Disking	1	4	8	.....	.75
Harrowing	1	4	35	.....	.17
Subsoiling	1	3	3½	.....	1.43
Drilling	1	4	15	.....	.40
Cultivating	1	4	16	.....	.38
Listing	1	4	10	.....	.60
Harvesting:					
Cutting and binding	1	4	15	$0.40	.93
Shocking	1	.....	.....	.13	
Twine	.....	.....	.....	.25	
Binder wear and repair	.....	.....	.....	.15	

[1] The cost of thrashing is not included in the cost per acre, but it is estimated at 10 cents per bushel and deducted from the price of 80 cents in the granary, thus giving a value of 70 cents per bushel in the shock.

The costs of hauling, stacking, and thrashing are not included in the per-acre cost of production because they can be calculated more accurately on the basis of cost per bushel, as hereafter explained.

The average farm price of wheat used in these computations is based on the data given in Table III, furnished by the Bureau of Crop Estimates. The four States of Kansas, Nebraska, North Dakota, and South Dakota were selected because their extensive wheat production has given them established market prices, which are not greatly influenced by local conditions.

TABLE III.—*Average price of spring wheat at the farm granary for 10 years in four States of the Great Plains area.*

[The quotations are given in cents per bushel. Those for the year 1914 are for the date of Nov. 1; in other years Dec. 1 is taken as the date.]

Year.	North Dakota.	South Dakota.	Nebraska.	Kansas.	Average.	Year.	North Dakota.	South Dakota.	Nebraska.	Kansas.	Average.
1905	69	67	66	71	68½	1911	89	91	87	91	89½
1906	63	61	57	58	59¾	1912	69	69	69	74	70¼
1907	87	89	79	82	84¼	1913	73	71	71	79	73½
1908	92	92	84	88	89	1914	97	90	92	94	94¼
1909	92	90	89	96	91¾						
1910	90	89	80	84	85¾	Average.	82	81	77	82	80½

Table III shows that the average farm price of wheat on December 1 for the past 10 years has been, in round numbers, 80 cents per bushel. It costs about 10 cents per bushel to take the grain from the shock, thrash it, and put it in the granary on the farm. This cost per bushel does not vary greatly with the yield and is therefore a fixed price per bushel instead of a fixed price per acre, as is the case with the other costs of production. It is therefore obvious that the relative profits of producing wheat under the different methods can best be determined by finding the difference between the fixed cost per acre and the value per acre of the grain at the point where the

fixed cost per acre ends, which, as before stated, is when the grain is in the shock. Knowing that the average farm value of wheat in the granary is 80 cents per bushel, and that it costs 10 cents per bushel to take it from the shock, thrash it, and put it in the granary, it is obvious that it would be worth 70 cents per bushel in the shock. This valuation of 70 cents per bushel has therefore been used as a basis for calculating the relative crop values, costs, and profits per acre of these various methods.

In conformity with the foregoing explanation, Table IV gives in detail the cost of producing wheat in the shock, expressed in dollars and cents, and in bushels per acre at 70 cents per bushel in the shock.

TABLE IV.—*Cost per acre of producing wheat in the shock in the Great Plains area, showing averages of data from eight stations.*

Method of preparation.	Number of operations.						Cost of preparation.	Cost per acre.			Interest and taxes.	Total cost of production.	
	Plowing.	Harrowing.	Disking.	Subsoiling.	Listing.	Drilling.		Seed.	Drilling.	Harvesting.		Per acre.	In bushels at 70 cents per bushel.
Disked corn land	.....	1.3	1	.....	.....	.....	$0.97	$0.85	$0.40	$0.93	$1.60	$4.75	6.8
Listed	.....	1.6	1.2	.....	1	.....	1.77	.85	.40	.93	1.60	5.55	7.9
Spring plowed	1	1.3	.5	.....	.....	.....	2.31	.85	.40	.93	1.60	6.09	8.7
Fall plowed	1	2.3	.9	.....	.....	.....	2.78	.85	.40	.93	1.60	6.56	9.4
Subsoiled	1	1.7	.9	0.5	.....	.....	3.39	.85	.40	.93	1.60	7.17	10.2
Summer tilled	1.5	9.2	2.6	.....	.....	.....	6.12	.85	.40	.93	3.20	11.50	16.4
Green manured:													
With rye [1]	2	6.5	2.4	.....	.....	1	7.73	.85	.40	.93	3.20	13.11	18.7
With peas [2]	2	5.8	2.7	.....	.....	1	10.73	.85	.40	.93	3.20	16.11	23.0
Average cost of green manuring	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.61	20.8

[1] The cost of rye for seeding one acre is estimated at $1.
[2] The cost of peas for seeding one acre is estimated at $4.

RESULTS AT THE SEVERAL STATIONS.

Accompanying the presentation of the results for each station is a brief soil description, with particular reference to the depth of the soil and its water-holding capacity. Only such information is given as is necessary to understand fully the interpretation of the results.

JUDITH BASIN FIELD STATION.

The field station at Moccasin, Mont., in the Judith Basin, is located on a heavy clay soil of limestone origin. The soil is apparently very rich in available fertility. It is underlain, at a depth of approximately 3 feet, by a limestone gravel that is closely cemented with lime materials. The gravel subsoil, which extends to a depth of about 30 feet, is practically free from soil. While it is so closely cemented that it does not unduly drain the soil, it is not of a character that allows the storage of available water or the development of roots within it. The presence of gravel in the surface soil does not

permit the taking of satisfactory samples for the study of soil moisture. Enough has been done, however, to make certain that only a limited supply of water available to the crop can be stored in the soil. This shallowness of the soil and the consequent limitation of the supply of water that can be stored in it and recovered by a crop make the crop dependent in large part upon the rains that fall while the crop is growing.

TABLE V.—*Yields and cost of production of spring wheat by different methods at the Judith Basin Field Station, 1909 to 1914, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).						
		1909	1910	1911	1912	1913	1914	Average.
Fall plowed:								
Corn	2	31.3	13.2	21.4	[a] H	24.9	18.1	21.8
Oats	2	36.8	11.5	24.7	H	23.5	19.1	23.2
Wheat	1	33.4	14.0	22.0	H	18.5	15.8	20.7
Total or average	5	33.9	12.7	22.8	.....	23.1	18.0	22.1
Spring plowed:								
Corn	1	33.1	11.6	21.3	H	23.8	18.5	21.7
Oats	2	[b] 31.6	10.0	20.8	H	24.1	18.1	20.9
Wheat	2	35.6	9.2	24.1	H	25.4	16.7	22.2
Total or average	5	[c] 34.0	10.0	22.6	.....	24.5	17.6	21.7
Listed: Wheat	1	33.3	8.3	26.5	H	23.3	17.1	21.7
Subsoiled: Wheat	1	36.3	15.0	23.5	H	22.8	16.5	22.8
Disked: Corn	8	35.0	10.8	23.9	H	23.6	19.4	22.5
Green manured:								
Rye	1	34.0	9.0	19.0	H	28.0	15.1	21.0
Peas	1	28.3	11.0	20.5	H	20.5	18.3	19.7
Total or average	2	31.2	10.0	19.8	.....	24.3	16.7	20.4
Summer tilled	4	[d] 34.1	7.2	20.1	H	22.9	19.5	20.8
Average of all 26 plats	.....	34.1	10.6	22.6	.....	23.6	18.4	21.9

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Fall plowed (5 plats).	Spring plowed (5 plats).	Disked (8 plats.)	Listed (1 plat).	Subsoiled (1 plat).	Green manured (2 plats).	Summer tilled (4 plats).	Corn (11 plats).	Small grain (9 plats).
Yields of grain:									
1909 ..... bushels	33.9	[c] 34.0	35.0	33.3	36.3	31.2	[d] 34.1	[e] 34.1	[f] 34.9
1910 ..... do	12.7	[c] 10.0	10.8	8.3	15.0	10.0	[d] 7.2	[e] 11.3	[f] 11.1
1911 ..... do	22.8	[c] 22.6	23.9	26.5	23.5	19.8	20.1	23.2	[f] 23.8
1912 ..... do	H	H	H	H	H	H	H	H	H
1913 ..... do	23.1	24.5	23.6	23.3	22.8	24.3	22.9	23.8	23.4
1914 ..... do	18.0	17.6	19.4	17.1	16.5	16.7	19.5	19.1	17.5
Average	22.1	21.7	22.5	21.7	22.8	20.4	20.8	21.9	22.1
Crop value, cost of production, etc.:									
Value	$15.47	$15.19	$15.75	$15.19	$15.96	$14.28	$14.56	.....	.....
Cost	6.56	6.09	4.75	5.55	7.17	14.61	11.50	.....	.....
Profit or loss	8.91	9.10	11.00	9.64	8.79	— .33	3.06	.....	.....

[a] H=Destroyed by hail.
[b] Yield of 1 plat only.
[c] Average of 4 plats.
[d] Average of 3 plats.
[e] Average of 10 plats.
[f] Average of 8 plats.

The most significant fact shown by Table V is the lack of material differences in yield resulting either from different methods of handling the soil in preparation for spring wheat or from the effect of the crop immediately preceding. This indicates that the place given to spring wheat in a rotation is comparatively unimportant. This is rather to be expected when the factors that determine production are understood in the light of recent information. There is not space here to discuss the subject, but suffice it to say: (1) On this rich, virgin, limestone soil, production is not immediately dependent upon increased fertility or greatly influenced by additions to or removal of its elements; (2) the shallowness of the soil where it is underlain by nonfunctioning gravel, together with the usually heavy spring rains, makes it impossible to realize the benefits that might be expected to accrue from methods of cultivation calculated to add to the total moisture supply by storage of moisture in the soil.

The problems appear to be those of good seed, good stand, freedom from weeds, and getting work done in proper season rather than those of certain methods of tillage. How soon results may become apparent from rotations that either add to or take from the fertility of the soil, it is impossible to predict.

The variations in yields have been so small up to the present time that it is possible all may be within the limits of experimental error or due to variations existing in the soil. It would therefore be unprofitable to discuss in detail the small variations that appear. The results are, however, of great importance in the evidence they offer that no one of the methods tried is essential to success in the growth of spring wheat and in the consequent freedom allowed in arranging a cropping system which need not necessarily include any unduly expensive or laborious method as a requisite of production.

Since there are no essential differences in yields from different methods at this station, it follows that the relative profit or loss has been largely determined by the cost of production. The spring wheat crop has been raised at a profit by all methods except that of green manuring. The largest profit has been obtained from disked corn ground. The value of it as a farm practice would depend upon the profitable growth or utilization of the corn crop in a farming system.

The next highest profits have been obtained from listing instead of plowing. This again is due to the low cost of preparation. While the yield from summer tillage has been about the same as from other methods, the increased cost of this method has been sufficient to reduce the profit from $11 per acre on disked corn ground to $3.06 per acre on summer-tilled land.

The heavy cost of green manuring has caused it to be done at the nominal loss of 33 cents per acre, when its whole cost is charged to the first crop that follows it. From the standpoint of actual yields

in bushels per acre it appears that no particular method of preparation for spring wheat is essential at this station. From the standpoint of profits per acre it would appear that the greatest profits are derived from the least expensive methods.

HUNTLEY FIELD STATION.

The field station at Huntley, Mont., is located in the valley of the Yellowstone River at the foot of the first bench. The soil is a heavy gumbo to a depth of about 8 feet. Underlying the soil is a considerable depth of free-drained gravel. This soil carries a large proportion of available water and allows deep feeding of the crop. It is consequently possible to store in it a maximum quantity of water that can be recovered by the crop.

TABLE VI.— *Yields and cost of production of spring wheat by different methods at the Huntley Field Station, 1913 and 1914.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).			Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).		
		1913	1914	Average.			1913	1914	Average.
Fall plowed:					Listed: Wheat	1	16.5	19.5	18.0
Corn	1	19.3	21.5	20.4	Subsoiled: Wheat	1	14.5	17.5	16.0
Oats	2	15.8	27.8	21.8	Disked: Corn	8	18.2	26.5	22.4
Wheat	1	11.8	20.2	16.0	Green manured:				
Total or average	4	15.7	24.3	20.0	Rye[1]	1	15.0	26.0	20.5
Spring plowed:					Peas	1	21.3	26.8	24.1
Corn	1	18.6	24.6	21.6	Total or average	2	18.2	26.4	22.3
Oats	1	14.3	24.8	19.6	Summer tilled	3	25.5	26.3	25.9
Wheat	1	16.0	18.3	17.2	Average of all 22 plats		18.2	24.8	21.5
Total or average	3	16.3	22.6	19.5					

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Fall plowed (4 plats).	Spring plowed (3 plats).	Disked (8 plats).	Listed (1 plat).	Subsoiled (1 plat).	Green manured (2 plats).	Summer tilled (3 plats).	Corn (10 plats).	Small grain (7 plats).
Yields of grain:									
1913.....bushels..	15.7	16.3	18.2	16.5	14.5	18.2	25.5	18.4	15.0
1914.....do....	24.3	22.6	26.5	19.5	17.5	26.4	26.3	25.8	22.3
Average.....	20.0	19.5	22.4	18.0	16.0	22.3	25.9	22.1	18.7
Crop value, cost of production, etc.:									
Value.....	$14.00	$13.65	$15.68	$12.60	$11.20	$15.61	$18.13	.....	.....
Cost.....	6.56	6.09	4.75	5.55	7.17	14.61	11.50	.....	.....
Profit.....	7.44	7.56	10.93	7.05	4.03	1.00	6.63	.....	.....

[1] Barley was used in place of rye in 1913.

The results of only two years are available for study from the Huntley station. Both were years of good to heavy production, but years when production was determined to a considerable degree by the amount of water stored in the soil at seeding time. There was consequently rather sharp response to those methods that start a crop with more available soil water than others.

The highest average yield, 25.9 bushels per acre, has been obtained from summer tillage. The next highest yield, 24.1 bushels, has been from the use of peas as green manure. Disked corn ground with a yield of 22.4 bushels has been better than corn ground plowed either in fall or spring. The data on the effects of fall and spring plowing of either corn ground, wheat, or oat stubble being rather contradictory and inconsistent among themselves, are hardly sufficient to admit the drawing of conclusions. Indications are that marked differences are not to be expected. The same lack of significant difference exists between the yields from listing and plowing. The yields from subsoiled land have just equalled those from land similarly treated in every way except subsoiling. Green manure, on the average, was productive of yields intermediate between those on summer-tilled ground and those on cropped ground. The crop raised in 1913 where peas were plowed under was much superior to that raised where barley was plowed under. In 1914 there was little difference between the crop after peas and that after winter rye.

Wheat has been produced at a profit by all methods. The greatest profit, $10.93 per acre, has come from disked corn land. This is due both to high yield and low cost of preparation. Between fall plowing, spring plowing, and listing there is little difference, the profits from them exceeding $3 per acre less than from disked corn ground. Subsoiling, on account of its low yield and higher cost, has reduced the profits to $4.03 per acre. The high cost of production on summer fallow has overcome the high yield to the extent that the profit from it has been somewhat less than that realized from land cropped every year. The least profit, $1 per acre, has been from the use of green manure.

WILLISTON FIELD STATION.

The experimental work at the Williston Field Station, in North Dakota, is conducted on a silt soil that carries a considerable proportion of available water and on which the depth of feeding is limited only by the depth to which the character of the crop limits its development of roots.

The results of five years are available for study from Williston station. The production for two of these years was very heavy, the average yield from all plats in 1912 being the highest yet recorded in this work. The year 1913 was one of good but not excessive

yields, while in 1910 and 1911 nearly all yields were so low as to be practical failures. With this wide diversity in seasons and yields, the results from year to year have been fairly consistent, the most serious departure being the low yield on disked corn ground in 1914. Minor differences, it is true, have been manifested, particularly as to the relative merits of fall and spring plowing, but on the whole there is a remarkable uniformity.

TABLE VII.—*Yields and cost of production of spring wheat by different methods at the Williston Field Station, 1910 to 1914, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).					
		1910	1911	1912	1913	1914	Average.
Fall plowed:							
Corn	1	0.7	1.8	36.5	16.1	23.3	15.7
Oats	2	.9	1.7	35.1	9.5	31.0	15.6
Wheat	1	1.3	2.3	33.8	11.7	22.5	14.3
Total or average	4	.9	1.9	35.1	11.7	26.9	15.3
Spring plowed:							
Corn	1	.7	5.5	38.2	14.4	26.8	17.1
Oats	1	1.8	4.0	32.2	13.0	31.5	16.5
Wheat	1	1.7	2.7	25.2	16.8	23.8	14.0
Total or average	3	1.4	4.1	31.9	14.7	27.4	15.9
Disked: Corn	7	.9	5.8	39.7	15.3	19.5	16.2
Green manured:							
Rye	1	2.8	.8	36.0	18.8	37.3	19.1
Peas	1	2.0	2.5	33.0	19.7	32.7	18.0
Total or average	2	2.4	1.7	34.5	19.3	35.0	18.6
Summer tilled	3	4.9	8.2	39.9	17.8	30.3	20.2
Average of all 19 plats		1.8	4.6	37.0	15.2	25.7	16.9

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.					Previous crop.	
	Fall plowed (4 plats).	Spring plowed (3 plats).	Disked (7 plats).	Green manured (2 plats).	Summer tilled (3 plats).	Corn (9 plats).	Small grain (5 plats).
Yields of grain:							
1910 bushels	0.9	1.4	0.9	2.4	4.9	0.9	1.3
1911 do	1.9	4.1	5.8	1.7	8.2	5.3	2.5
1912 do	35.1	31.9	39.7	34.5	39.9	39.2	32.3
1913 do	11.7	14.7	15.3	19.3	17.8	15.3	12.1
1914 do	26.9	27.4	19.5	35.0	30.3	20.8	27.9
Average	15.3	15.9	16.2	18.6	20.2	16.3	15.2
Crop value, cost of production, etc.:							
Value	$10.71	$11.13	$11.34	$13.02	$14.14	.....	.....
Cost	6.56	6.09	4.75	14.61	11.50	.....	.....
Profit or loss	4.15	5.04	6.59	— 1.59	2.64	.....	.....

The highest average yield, 20.2 bushels per acre, has been obtained from summer tillage. The plowing under of rye or peas for green manure has resulted in the next highest average yield. Spring rye

is used at this station and is plowed under at the same time as peas. This is done in early summer, and the land is then handled as an intensively cultivated bare fallow until seeding time. While results have fluctuated between the two crops used for green manure from year to year, the variations have probably been within the limits of experimental error.

As to the relative merits of fall and spring plowing and disking as a means of preparation for wheat, the yields show such lack of consistency from year to year that it would be unwise to attempt to draw general conclusions from the data at hand, unless it were that the results attending these practices will vary with the season and that no particular one is essential to success.

Wheat, on both spring and fall plowing after oats, appears on the average to yield better than wheat after wheat.

When the cost of production is figured, it is found that the average yields of the five years under study have been sufficient to allow a profit from all methods except that of green manure. While the yield from this method was next to the highest, it was not enough to offset the heavy cost of production.

The greatest profit, $6.59 per acre, was obtained from disked corn ground, and the least, $2.64 per acre, from summer tillage.

DICKINSON FIELD STATION.

The soil at the Dickinson Field Station, in North Dakota, is somewhat lacking in uniformity. In general, however, it is characterized as a sandy loam to a depth of approximately 5 feet. Below this depth is a lighter soil, which in some cases becomes very sandy or pure sand. The soil has the capacity to retain a large proportion of water and to give up to the crop a large share of what is retained. This feature, in connection with the depth to which a crop may feed, makes it possible to store in this soil an exceptionally large quantity of water that can be recovered by the crop.

While records for the Dickinson station are available for study since and including 1908, the yields and averages are made up from the results of six years, as the crop of 1912 was destroyed by hail shortly after heading. As the fall plowing that year was done exceptionally early, on account of the opportunity offered by the early removal of the crop, it shows up relatively much better than usual in 1913. On this account it approached summer tillage and green manure both in opportunity and in results.

Four of the years studied have been years of heavy wheat production from all methods. The year 1911 was one of low general average, but of exceptional differences between methods. It was a year of drought during the late stages of growth, which made it possible to

realize a maximum benefit from the water previously stored in the soil by some methods. The crop of 1914 was damaged at least 25 per cent by hail shortly before harvest.

TABLE VIII.— *Yields and cost of production of spring wheat by different methods at the Dickinson Field Station, 1908 to 1914, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).							
		1908	1909	1910	1911	1912	1913	1914	Average.
Fall plowed:									
Corn	1	35.0	37.3	24.0	4.7	[1] H	27.5	15.9	24.1
Manured corn	1	33.8	40.7	22.5	3.2	H	27.5	13.2	23.5
Oats	2	19.7	34.7	19.2	.7	H	26.8	11.3	18.7
Wheat	1	17.7	25.2	18.2	1.4	H	20.5	8.9	15.3
Total or average	5	25.2	34.5	20.6	2.1	.....	25.8	12.1	20.1
Spring plowed:									
Corn	1	35.0	39.7	27.8	14.0	H	28.0	12.0	26.1
Oats	1	18.7	30.7	18.1	1.3	H	17.0	15.2	16.8
Wheat	1	24.3	26.8	17.4	5.7	H	13.5	10.5	16.4
Total or average	3	26.0	32.4	21.1	7.0	.....	19.5	12.6	19.8
Disked: Corn	9	32.3	37.9	22.7	3.8	H	27.8	15.3	23.3
Green manured:									
Rye	2	32.1	38.3	19.7	5.6	H	28.0	20.0	24.0
Peas	2	30.0	36.0	17.4	1.2	H	24.8	18.6	21.3
Sweet clover	1	31.0	32.3	19.0	1.3	H	24.5	13.7	20.3
Total or average	5	31.0	36.1	18.6	3.0	.....	26.0	18.2	22.2
Summer tilled	3	33.6	36.9	26.0	22.1	H	27.2	19.2	27.5
Average of all 25 plats	.....	30.0	36.1	21.7	5.9	.....	25.9	15.4	22.5

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.					Previous crop.	
	Fall plowed (5 plats).	Spring plowed (3 plats).	Disked (9 plats).	Green manured (5 plats).	Summer tilled (3 plats).	Corn (12 plats).	Small grain (5 plats).
Yields of grain:							
1908.....bushels..	25.2	26.0	32.3	31.0	33.6	33.0	20.0
1909.....do....	34.5	32.4	37.9	36.1	36.9	38.3	30.4
1910.....do....	20.6	21.1	22.7	18.6	26.0	23.2	18.4
1911.....do....	2.1	7.0	3.8	3.0	22.1	4.9	2.0
1912.....do....	H	H	H	H	H	H	H
1913.....do....	25.8	19.5	27.8	26.0	27.2	27.8	20.9
1914.....do....	12.1	12.6	15.3	18.2	19.2	14.9	11.4
Average	20.1	19.8	23.3	22.2	27.5	23.7	17.2
Crop value, cost of production, etc.:							
Value	$14.07	$13.86	$16.31	$15.54	$19.25	.....	.....
Cost	6.56	6.09	4.75	14.61	11.50	.....	.....
Profit	7.51	7.77	11.56	.93	7.75	.....	.....

[1] H=Destroyed by hail.

Some indications shown in Table VIII are rather striking. The effect of the preceding crop and the preparation for spring wheat divide rather sharply into two groups, as indicated by the results obtained. When wheat followed summer tillage, corn, or green manure it has given comparatively high yields. When it followed

small grains, the yields have been comparatively low, regardless of preparation.

As between oats and wheat, whether spring or fall plowed, or between spring or fall plowing of either wheat or oat stubble, no decision is apparently to be made from the data at hand. The advantage, if any, seems to be in favor of fall-plowed oat stubble.

The highest average yield, and it is a very high average, 27.5 bushels per acre, has been obtained by summer tillage. But spring-plowed corn ground has averaged 26.1 bushels; fall-plowed corn ground, 24.1 bushels; and nine plats of disked corn ground, well distributed over the field, have averaged 23.3 bushels per acre. Considering the importance of corn in a general farming system and the small advantage shown by summer tillage over corn land in producing wheat, it would seem that even here where summer tillage has been productive of such high yields, it can have no regular place in a permanent farming system.

The use of manure on corn does not appear to have had as yet any appreciable effect upon the wheat that followed the corn.

The use of winter rye plowed under as green manure has thus far been productive of considerably better results than the similar use of either peas or sweet clover. This difference in yield is probably due to the fact that winter rye may be plowed under considerably earlier than either the peas or sweet clover.

Both high yield and low cost of production have combined to give the greatest profit per acre, $11.56, from wheat on disked corn ground. The high yield of wheat on summer tillage has been scarcely sufficient to overcome the increased cost of this method. It shows a profit of $7.75 per acre, while spring-plowed land that had been cropped shows a profit of $7.77 per acre, and fall-plowed land shows $7.51. While green manuring shows about the same production as land from which a crop was removed, the high cost of the method has reduced the profit from it to 93 cents per acre.

EDGELEY FIELD STATION.

The field station at Edgeley, N. Dak., is located on a soil that is derived from the decomposition of shale. Shale in undecomposed particles is found very near the surface. In the third foot the shale, while broken and offering fairly free passage to water, is not as yet broken down into soil. The depth of feeding of crops is practically limited to the first 2 feet. The first foot carries an exceptionally large proportion of water available to the crop. The limited depth of soil that functions in the storage of water and in the development of the crop, however, limits the supply of water that can be carried in the soil to about half of that carried by soils of greater depths. This makes the crop peculiarly dependent upon rains that fall while it is growing.

TABLE IX.—*Yields and cost of production of spring wheat by different methods at the Edgeley Field Station, 1907 to 1914, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).								
		1907	1908	1909	1910	1911	1912	1913	1914	Average.
Fall plowed:										
Corn	1	12.6	20.8	32.5	6.3	1.5	36.7	23.0	16.8	18.8
Oats	2	9.5	13.0	27.6	4.7	1.0	30.3	15.9	17.1	14.9
Wheat	1	7.0	15.3	23.3	5.2	.5	27.0	12.1	9.2	12.5
Total or average	4	9.7	15.5	27.7	5.2	1.0	31.1	16.7	15.1	15.3
Spring plowed:										
Corn	2	[a] 13.2	[a] 15.8	28.0	4.7	.8	35.5	22.7	16.7	17.2
Oats	1	4.2	13.5	25.8	3.8	.2	31.3	20.6	17.5	14.6
Wheat	1	4.1	13.3	28.3	4.0	.7	35.0	16.3	11.3	14.1
Total or average	4	7.2	14.2	27.5	4.3	.6	34.3	20.6	15.5	15.5
Disked: Corn	12	[b] 13.4	[c] 18.1	27.8	5.7	2.6	33.6	23.6	17.0	17.7
Green manured:										
Rye	1	10.5	19.8	30.5	2.6	.3	36.7	21.8	12.8	16.9
Peas	1	10.2	18.2	28.6	6.3	.2	37.5	22.1	20.3	17.9
Sweet clover	1	.....	11.7	23.1	3.6	.2	34.2	24.5	14.3	15.9
Total or average	3	[d] 10.4	16.6	27.4	4.2	.2	36.1	22.8	15.8	16.7
Summer tilled	5	[d] 10.9	15.8	27.5	8.0	3.2	35.4	26.1	16.0	17.9
Average of all 28 plats	.....	[e] 10.6	[f] 16.6	27.6	5.7	1.9	33.9	22.5	16.2	16.9

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.					Previous crop.	
	Fall plowed (4 plats).	Spring plowed (4 plats).	Disked (12 plats).	Green manured (3 plats).	Summer tilled (5 plats).	Corn (15 plats).	Small grain (5 plats).
Yields of grain:							
1907.....bushels..	9.7	[g] 7.2	[b] 13.4	10.4	10.9	[h] 13.2	6.9
1908.....do....	15.5	[g] 14.2	[c] 18.1	16.6	15.8	18.2	13.6
1909.....do....	27.7	27.5	27.8	27.4	27.5	28.1	26.5
1910.....do....	5.2	4.3	5.7	4.2	8.0	5.6	4.5
1911.....do....	1.0	.6	2.6	.2	3.2	2.3	.7
1912.....do....	31.1	34.3	33.6	36.1	35.4	[i] 34.0	30.8
1913.....do....	16.7	20.6	23.6	22.8	26.1	23.4	16.1
1914.....do....	15.1	15.5	17.0	15.8	16.0	17.0	14.4
Average	15.3	15.5	17.7	16.7	17.9	17.7	14.2
Crop value, cost of production, etc.:							
Value	$10.71	$10.85	$12.39	$11.69	$12.53	.....	.....
Cost	6.56	6.09	4.75	14.61	11.50	.....	.....
Profit or loss	4.15	4.76	7.64	— 2.92	1.03	.....	.....

[a] Yield of 1 plat.
[b] Average of 5 plats.
[c] Average of 9 plats.
[d] Average of 2 plats.
[e] Average of 18 plats.
[f] Average of 22 plats.
[g] Average of 3 plats.
[h] Average of 7 plats.
[i] Average of 11 plats.

This station presents for study the results of eight years. Five of these have been years of good to heavy production. In one year the production was light, in another it was very poor, while the remaining year was one of practical failure of all methods under study.

The wide differences in yield resulting from different methods of preparation that were obtained at some stations during some years

are not exhibited at this station in either the good or the poor years. The reason for this is to be found in the shallowness of the soil that functions for the growth of the crop and for the storage of water that can be recovered by the crop. This shallowness makes the crop dependent for its growth upon seasonal rains that fall while the crop is growing. It may be that this shallowness makes it possible to realize quicker results from the cumulative effect of the use of manure than would be realized on deeper soils.

The relative merits of fall or spring plowing of either wheat or oat stubble seem to be a matter of season. In no case does it make a great difference, and on the average the difference has been negligible. It should be noted that the result from the one plat of wheat on spring-plowed wheat land deserves but little consideration. On account of its location and of continual spring plowing, it has accumulated blowing soil until it is now built up several inches above its original level, or the present level of other plats.

Fall-plowed corn ground has apparently had an advantage over corn ground, either spring plowed or disked, in preparation for wheat. The results are determined from 1 plat of fall-plowed corn as against 12 plats of disked corn ground, which are distributed over the whole field; the advantage, therefore, may be due to a particularly favorable location of the one plat.

With the exception of the high yield of wheat in 1914 on peas used as green manure, there is little choice between them and rye similarly used. Both have been better than sweet clover plowed under. The average yield of wheat following peas as green manure is exactly the same as the average on summer tillage.

Summer tillage has given an average yield of 17.9 bushels per acre for the eight years. This is exceeded only by the yield on fall-plowed corn ground. When this is compared with a similar average yield of 17.7 bushels per acre from disked corn ground and 14.2 bushels from wheat under all methods following small-grain crops, it is seen that summer tillage is an unnecessary practice and one not to be recommended for this section. This is brought out strongly by Table IX, which shows the cost of production and the resultant profit or loss from each method. Disked corn ground shows an average 8-year profit of $7.64 per acre, spring plowing $4.76, and fall plowing $4.15, while the cost of summer tillage has reduced the profit to $1.03. The average loss for the green manures has been $2.92 per acre.

HETTINGER FIELD STATION.

The soil at the Hettinger (N. Dak.) station is a heavy clay loam. The seasons during which the work has been carried on have been such that the results of soil-moisture study are not yet conclusive in determining the proportion of water that can be stored in the soil

and recovered by a crop. It is probable, however, that the depth of feeding is not limited by any physical peculiarity of the soil and that the quantity of water that can be stored is large. It is reasonable therefore to expect that on this soil the maximum effect will be realized from methods of tillage calculated to store water.

TABLE X.—*Yields and cost of production of spring wheat by different methods at the Hettinger Field Station, 1912, 1913, and 1914.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).			
		1912	1913	1914	Average.
Fall plowed:					
Manured corn	1	9.0	18.0	11.7	12.9
Corn	1	13.8	17.8	12.0	14.5
Oats	2	17.8	12.7	14.1	14.9
Wheat	1	12.0	10.7	6.2	9.6
Total or average	5	14.1	14.4	11.6	13.4
Spring plowed:					
Corn	1	13.0	26.3	10.3	16.5
Oats	1	8.3	16.5	10.8	11.9
Wheat	1	14.3	13.8	10.0	12.7
Total or average	3	11.9	18.9	10.4	13.7
Disked:					
Corn	11	17.5	18.4	11.7	15.9
Potatoes	1	11.7	16.7	11.7	13.4
Total or average	12	17.0	18.3	11.7	15.7
Green manured:					
Rye	2	16.0	21.3	11.4	16.2
Peas	1	18.3	23.5	9.0	16.9
Sweet clover	1	11.2	8.2	7.8	9.1
Total or average	4	15.4	18.6	9.9	14.6
Summer tilled	8	19.9	29.6	11.8	20.4
Average of all 32 plats	.....	16.6	20.6	11.4	16.2

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.					Previous crop.		
	Fall plowed (5 plats).	Spring plowed (3 plats).	Disked (12 plats).	Green manured (4 plats).	Summer tilled (8 plats).	Corn (14 plats).	Small grain (5 plats).	Potatoes (1 plat).
Yields of grain:								
1912.....bushels..	14.1	11.9	17.0	15.4	19.9	16.3	14.0	11.7
1913.....do....	14.4	18.9	18.3	18.6	29.6	18.6	13.3	16.7
1914.....do....	11.6	10.4	11.7	9.9	11.8	11.6	11.0	11.7
Average.....	13.4	13.7	15.7	14.6	20.4	15.5	12.8	13.4
Crop value, cost of production, etc.:								
Value.....	$9.38	$9.59	$10.99	$10.22	$14.28	.....	.....	.....
Cost.....	6.56	6.09	4.75	14.61	11.50	.....	.....	.....
Profit or loss.....	2.82	3.50	6.24	−4.39	2.78	.....	.....	.....

The results of three years at this station are available for study. The most striking things shown by the arrangement of yields for the present study are the increased production of wheat on summer tillage, on rye and peas as green manure, and on corn ground either disked or plowed in the spring. When yields are studied in connection with cost of production, it is seen that, owing to good yield and cheap cost of preparation, the greatest profit, $6.24 per acre, has been obtained from wheat on disked ground. Of the disked plats,

11 were corn ground and 1 was potato ground. Spring plowing has been productive of an average profit of $3.50 and fall plowing of $2.82. Despite the increased yield on summer tillage, the high cost of the method has reduced the profits from it to $2.78 per acre. The still higher cost of preparation and the lower yields from green manuring have contributed to make it show a loss of $4.39 per acre.

BELLE FOURCHE FIELD STATION.

The field-station farm near Newell, S. Dak., on the Belle Fourche Reclamation Project, is located on a heavy gumbo clay soil, which is derived from the decomposition of Pierre shale. From the soil at the surface there is a rapid change to broken but undecomposed shale. Near the bottom of the second foot is a comparatively impervious layer of soil. The first foot and at least a part of the second foot carry a large proportion of available water. It is probable that little use is made of either water or soil below the first 2 feet. In spite of the heavy soil and the large quantity of water that can be obtained by the plant from that portion of it near the surface, the shallowness of feeding reduces the quantity of water that can be carried in the soil to about one-half of that available on deeper soils. The result of this is shown in the yields.

While the results of six years are available from this station, two of them have been years of total failure of the wheat crop. These failures were due to drought so extreme that no methods of culture were able to overcome it. A third year produced some light yields, but the crop was practically a failure for all methods. These three dry years in succession afforded no opportunity to profit from methods calculated to store moisture. The rainfall was so light and its distribution so unfavorable as to make the accumulation of water in the soil impossible. In two other years there was production from all methods, but the yields were light. In only the first year of the series under consideration was the general production heavy.

Neither in the average of the series nor in any of the years within the series has there been evidenced sufficient difference in production to warrant an extended discussion of the relative merits of the methods under trial. The only partial exception to this statement is to be found in the advantage of summer tillage over other methods in resisting the dry seasons of 1913 and 1914. However, in 1913 it was able to produce only 15.6 bushels per acre, as against an average of 8.7 bushels on fall-plowed land that had been in crop the year before. In 1914 it produced an average of 16.1 bushels per acre, while the production on disked corn land was 10 bushels and on fall-plowed ground only 5.8 bushels per acre. In 1912 all the available water in the soil was used, but in no case was it sufficient to make a crop.

TABLE XI.— *Yields and cost of production of spring wheat by different methods at the Belle Fourche Field Station, 1909 to 1914, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).						
		1909	1910	1911	1912	1913	1914	Average.
Fall plowed:								
Corn	1	23.6	0	0	0	7.3	6.3	6.2
Oats	2	31.5	0	0	0	9.8	6.1	7.9
Wheat	1	23.3	0	0	0	7.9	4.8	6.0
Total or average	4	27.5	.....	.....	.....	8.7	5.8	7.0
Spring plowed:								
Corn	1	23.9	3.0	0	0	5.6	4.5	6.2
Oats	1	26.1	2.4	0	0	7.9	6.0	7.1
Wheat	1	23.8	2.8	0	0	6.2	4.0	6.1
Total or average	3	24.6	2.7	.....	.....	6.6	4.8	6.5
Listed: Wheat	1	28.7	0	0	0	9.5	6.8	7.5
Subsoiled: Wheat	1	28.5	0	0	0	6.8	4.7	6.7
Disked:								
Corn	10	29.8	3.8	0	0	10.3	10.0	9.0
Potatoes	1	27.5	1.7	0	0	12.3	11.3	8.8
Sorghum	1	26.8	.3	0	0	9.4	9.0	6.6
Total or average	12	28.9	3.3	.....	.....	10.4	10.0	8.8
Green manured:								
Rye	1	30.6	5.7	0	0	13.4	13.8	10.6
Peas	1	29.9	1.3	0	0	13.5	11.3	9.3
Sweet clover	2	24.5	0	0	0	12.0	13.9	8.4
Total or average	4	27.4	1.8	.....	.....	12.7	13.2	9.2
Summer tilled	5	32.7	4.3	0	0	15.6	16.1	11.5
Average of all 30 plats	.....	28.7	2.5	.....	.....	10.8	10.1	8.7

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.			
	Fall plowed (4 plats).	Spring plowed (3 plats).	Disked (12 plats).	Listed (1 plat).	Subsoiled (1 plat).	Green manured (4 plats).	Summer tilled (5 plats).	Corn (12 plats).	Small grain (7 plats).	Potatoes (1 plat).	Sorghum (1 plat).
Yields of grain:											
1909...bushels.	27.5	24.6	28.9	28.7	28.5	27.4	32.7	[a] 29.3	27.6	27.5	20.8
1910.....do....	0	2.7	3.3	0	0	1.8	4.3	3.4	.7	1.7	.3
1911.....do....	0	0	0	0	0	0	0	0	0	0	0
1912.....do....	0	0	0	0	0	0	0	0	0	0	0
1913.....do....	8.7	6.6	10.4	9.5	6.8	12.7	15.6	9.7	8.3	12.3	9.4
1914.....do....	5.8	4.8	10.0	6.8	4.7	13.2	16.1	9.3	5.5	11.3	9.0
Average.....	7.0	6.5	8.8	7.5	6.7	9.2	11.5	8.6	7.0	8.8	6.6
Crop value, cost of production, etc.:											
Value.....	$4.90	$4.55	$6.16	$5.25	$4.69	$6.44	$8.05	.....	.....	.....	.....
Cost.....	6.56	6.09	4.75	5.55	7.17	14.61	11.50	.....	.....	.....	.....
Profit or loss	−1.66	−1.54	1.41	− .30	−2.48	−7.17	−3.45	.....	.....	.....	.....

[a] Average of 11 plats.

The only method that shows a profit here is disked corn ground. This, on account of the low cost of preparation, shows an average annual profit of $1.41 per acre. All other methods indicate the

production of wheat at a loss ranging from 30 cents on listed land to $7.17 an acre on green manure. Generally speaking, the more expensive the method of preparation the greater the yield. But the yields did not increase in the same ratio as the expense; it accordingly follows that the less the expense of preparation the less the loss that attended the use of any method.

SCOTTSBLUFF FIELD STATION.

The work at Scottsbluff, Nebr., is conducted at a field station located on the North Platte Reclamation Project. The soil is a comparatively light, sandy loam. At a depth varying from 5 to 8 feet there is a sharp break from this soil to either sand or Brule clay. Above this point the soil offers no unusual resistance to the downward passage of water or the development of roots. Owing to its light character, however, it is possible to store in it only a moderate proportion of available water. While the evidence on this point is not yet complete, the amount of water that can be stored in this soil is known to be somewhat intermediate between the corresponding amounts that can be stored in the Belle Fourche and North Platte soils.

The results of three years are available for study at this station. All have been years of comparatively light yields, but one of them shows heavy production from one method.

Spring plowing has been generally better than fall, irrespective of whether it were wheat, oat, or corn stubble that was plowed. Marked benefit was apparently derived one year from the use of manure in growing the corn that preceded one plat of wheat.

Furrowing with a lister and leaving the ground rough through the winter instead of plowing was apparently beneficial one year, but of neutral value in the others.

Disked corn ground was the second best method in one year, but it seemed to be of little benefit in increasing production in the other two years. Disked corn ground has each year given larger returns of wheat than were obtained by plowing it either in spring or fall.

The results from green manure are not consistent either among themselves or in comparison with other methods. In average production it stands third on the list, being exceeded by summer tillage and disked corn ground.

The highest yields each year have been obtained from summer tillage. This method has an average yield of 19.9 bushels per acre as against 14 bushels, the next highest average, from disked corn ground.

TABLE XII.— *Yields and cost of production of spring wheat by different methods at the Scottsbluff Field Station, 1912, 1913, and 1914.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).			
		1912	1913	1914	Average.
Fall plowed:					
Corn	1	11.6	8.0	9.5	9.7
Manured corn	1	20.8	9.8	9.5	13.4
Oats	2	7.7	9.0	10.3	9.0
Wheat	1	6.3	7.8	6.7	6.9
Total or average	5	10.8	8.7	9.3	9.6
Spring plowed:					
Corn	1	17.3	11.3	11.0	13.2
Oats	1	11.7	9.5	12.0	11.1
Sorghum	1	18.7	11.2	9.0	13.0
Wheat	1	8.7	12.0	5.7	8.8
Total or average	4	14.1	11.0	9.4	11.5
Listed:					
Wheat	1	15.0	7.2	6.0	9.4
Subsoiled:					
Wheat	1	12.3	6.3	9.5	9.4
Disked:					
Corn	11	19.1	11.8	11.1	14.0
Green manured:					
Rye	1	15.0	13.0	13.6	13.9
Peas	1	11.7	14.2	12.0	12.6
Total or average	2	13.4	13.6	12.8	13.3
Summer tilled	3	27.8	18.1	13.8	19.9
Average of all 27 plats	27	17.0	11.6	10.7	13.1

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.		
	Fall plowed (5 plats).	Spring plowed (4 plats).	Disked (11 plats).	Listed (1 plat).	Subsoiled (1 plat).	Green manured (2 plats).	Summer tilled (3 plats).	Corn (14 plats).	Small grain (7 plats).	Sorghum (1 plat).
Yields of grain:										
1912..bush	10.8	14.1	19.1	15.0	12.3	13.4	27.8	18.6	9.9	18.7
1913 ...do	8.7	11.0	11.8	7.2	6.3	13.6	18.1	11.4	8.3	11.2
1914 ...do	9.3	9.4	11.1	6.0	9.5	12.8	13.8	10.9	8.6	9.0
Average	9.6	11.5	14.0	9.4	9.4	13.3	19.9	13.6	8.9	13.0
Crop value, cost of production, etc.:										
Value	$6.72	$8.05	$9.80	$6.58	$6.58	$9.31	$13.93	.....	.....	.....
Cost	6.56	6.09	4.75	5.55	7.17	14.61	11.50	.....	.....	.....
Profit or loss	.16	1.96	5.05	1.03	— .59	— 5.30	2.43	.....	.....	.....

Having next to the highest yield and the lowest cost of preparation, disked corn ground shows the greatest profit, $5.05 per acre. Other methods that show profits are spring plowing, summer tillage, listing, and fall plowing. Subsoiling and green manure show losses.

NORTH PLATTE FIELD STATION.

The work here presented was conducted on the table-land of the North Platte, Nebr., station. The soil is of the type generally known as loess. With the exception of the humus accumulated near the surface it is practically uniform to great depths. The storage and use of water is not limited by the depth of soil or any peculiarities in it. The development of roots is limited only by the physiological character of the crops grown and the available moisture. It is a soil on which maximum results from tillage methods would be expected.

TABLE XIII.—*Yields and cost of production of spring wheat by different methods at the North Platte Field Station, 1907 to 1914, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).								
		1907	1908	1909	1910	1911	1912	1913	1914	Average.
Fall plowed:										
Corn	2	22.5	28.7	21.3	7.6	0	6.4	4.1	5.5	12.0
Oats	2	26.3	27.3	16.0	6.8	0	4.7	1.3	6.1	11.1
Wheat	1	26.0	27.3	15.3	6.7	0	11.2	1.8	5.2	11.7
Total or average	5	24.7	27.8	18.0	7.1	.....	6.7	2.5	5.7	11.6
Spring plowed:										
Corn	1	23.7	24.0	17.2	5.2	0	5.3	1.5	5.0	10.2
Oats	1	20.8	17.5	16.7	8.7	0	8.8	1.8	2.2	9.6
Wheat	1	24.5	22.7	23.0	6.8	0	12.8	2.0	6.0	12.2
Sorghum	1	23.5	20.3	16.3	8.7	0	3.8	3.3	5.2	10.1
Total or average	4	23.1	21.1	18.3	7.4	.....	7.7	2.2	4.6	10.6
Disked:										
Corn	8	24.5	24.2	14.5	7.3	0	4.6	3.0	5.1	10.4
Potatoes	1	.....	.....	.....	.....	.....	5.2	4.2	6.9	5.4
Total or average	9	[a] 24.5	[a] 24.2	[a] 14.5	[a] 7.3	.....	[a] 4.6	3.1	5.3	10.5
Summer tilled	3	28.9	41.4	22.6	15.3	0	7.1	6.8	12.5	16.8
Average of all 19 plats	.....	24.7	26.3	17.1	8.7	.....	[b] 6.4	[c] 3.2	6.3	11.6

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.				Previous crop.		
	Fall plowed (5 plats).	Spring plowed (4 plats).	Disked (8 plats).	Summer tilled (3 plats).	Corn (11 plats).	Small grain (5 plats).	Sorghum (1 plat).
Yields of grain:							
1907 ..... bushels	24.7	23.1	24.5	28.9	24.1	24.8	23.5
1908 ..... do	27.8	21.1	24.2	41.4	25.0	24.4	20.3
1909 ..... do	18.0	18.3	14.5	22.6	16.0	17.4	16.3
1910 ..... do	7.1	7.4	7.3	15.3	7.1	7.2	8.7
1911 ..... do	0	0	0	0	0	0	0
1912 ..... do	6.7	7.7	4.6	7.1	5.0	8.4	5.8
1913 ..... do	2.5	2.2	3.0	6.8	3.0	1.6	3.3
1914 ..... do	5.7	4.6	5.1	12.5	5.2	5.1	5.2
Average ..... do	11.6	10.6	10.4	16.8	10.7	11.1	10.1
Crop value, cost of production, etc.:							
Value	$8.12	$7.42	$7.28	$11.76	.....	.....	.....
Cost	6.56	6.09	4.75	11.50	.....	.....	.....
Profit	1.56	1.33	2.53	.26	.....	.....	.....

[a] Average of 8 plats. [b] Average of 22 plats. [c] Average of 23 plats.

Some of the results of the work of eight years are exhibited in Table XIII. Three of these years have been productive of good to heavy crops of wheat; in four years the average yields were light; and in the remaining year under study the crop was a total failure on account of drought, together with some damage from grasshoppers. The general averages of spring-wheat yields for the eight years range from 9.6 to 16.8 bushels per acre, according to the preparation and previous cropping of the land. A comparison of the

wheat crops raised on corn ground, oat stubble, and wheat stubble with those on spring-plowed or fall-plowed ground after any crop, or on disked-corn ground as a preparation for wheat, shows no wide differences in yields. A small average difference in favor of fall over spring plowing is shown. Fall plowing of corn ground in preparation for wheat appears from the returns of two plats so treated to have been considerably better than either disking or spring plowing it.

The one plat of wheat on spring plowing following wheat has given an average yield of 12.2 bushels per acre. This plat is plowed shallow while the others are plowed deep, as heretofore explained. The departure of this method from the others in yield appears to have been dependent upon the seasons and is not consistent from year to year.

Summer tillage for wheat at this station seems to stand by itself as a means of increasing the yield. The largest increases in bushels from this method have been obtained in the best years. After the first year of a period of dry years, which began in 1910, summer tillage has not been able, except in 1914, to increase yields or even, in some cases, to maintain them at the standard set by less expensive methods. While it is not shown in the present study, a much greater response to summer tillage is obtained with winter wheat.[1] Consequently, in spite of the fact that this method has been productive on the average of more bushels per acre of spring wheat than any other, it will not find favor in farm management as a general practice for the growth of spring wheat.

When the cost of production is considered, it is seen that the yield obtained by summer tillage has been enough to pay for the cost of the method. For the eight years under study it shows an average profit of 26 cents per acre. Fall plowing and spring plowing show profits of only $1.56 and $1.33 per acre for the same period. The low cost of preparation is responsible for making disked corn ground show an average annual profit of $2.53.

While the spring wheat crop has been raised without much net profit, it seems that it might afford a market for the labor of men and teams and pay for the use of the land.

AKRON FIELD STATION.

The soil at the field station at Akron, Colo., is of a clay-loam type, locally known as "tight land." It is characterized in the native vegetation by a growth of short grass. As it carries in each unit section a considerable proportion of water available to the crop and as it offers no physical resistance to the development of roots, it is possible to store in it a large quantity of water available to a crop. It

[1] See Nebraska Experiment Station Bulletin 135.

is a soil on which maximum results from methods of tillage calculated to store water would be expected.

TABLE XIV.— *Yields and cost of production of spring wheat by different methods at the Akron Field Station, 1909 to 1914, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).						
		1909	1910	1911	1912	1913	1914	Average.
Fall plowing:								
Corn	1	19.2	11.2	3.4	30.3	1.4	14.3	13.3
Oats	3	10.3	5.8	3.7	18.8	.6	13.6	8.8
Wheat	[a] 2	10.3	6.2	2.1	17.5	.7	11.0	8.0
Total or average	5	12.1	6.9	3.1	20.6	.8	12.8	9.4
Spring plowing:								
Corn	1	20.8	15.3	1.3	26.5	6.8	18.5	14.9
Oats	1	14.3	6.3	.2	20.3	1.0	21.2	10.6
Wheat	[b] 2	12.2	8.9	2.9	21.3	4.8	22.2	12.1
Total or average	4	14.9	10.0	1.5	22.7	4.2	20.6	12.3
Listed: Wheat	1	9.6	7.1	1.2	17.2	2.1	14.2	8.6
Subsoiled: Wheat	1	11.2	5.5	1.5	16.0	.5	9.8	7.4
Disked: Corn	4	15.5	11.4	1.7	19.0	2.8	16.7	11.2
Green manured:								
Rye	1	14.7	11.7	3.7	19.2	1.5	15.3	11.0
Peas	1	12.0	12.4	1.7	20.3	1.5	13.3	10.2
Sweet clover	1	10.1	3.8	1.7	20.5	3.9	11.2	8.5
Total or average	3	12.3	9.3	2.4	20.0	2.3	13.3	9.9
Summer tilled	2	18.4	12.2	4.8	20.5	9.0	22.5	14.6
Average of all 20 plats	.....	13.8	9.2	2.5	20.0	2.9	16.5	10.8

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.						Previous crop.		
	Fall plowed (5 plats).	Spring plowed (4 plats).	Disked (4 plats).	Listed (1 plat).	Subsoiled (1 plat).	Green manured (3 plats).	Summer tilled (2 plats).	Corn (6 plats).	Small grain (9 plats).
Yields of grain:									
1909.....bushels..	12.1	14.9	15.5	9.6	11.2	12.3	18.4	17.0	11.2
1910.....do....	6.9	10.0	11.4	7.1	5.5	9.3	12.2	12.0	6.7
1911.....do....	3.1	1.5	1.7	1.2	1.5	2.4	4.8	1.9	2.3
1912.....do....	20.6	22.7	19.0	17.2	16.0	20.0	20.5	22.1	18.5
1913.....do....	.8	4.2	2.8	2.1	.5	2.3	9.0	3.2	1.3
1914.....do....	12.8	20.6	16.7	14.2	9.8	13.3	22.5	16.6	14.5
Average	9.4	12.3	11.2	8.6	7.4	9.9	14.6	12.1	9.1
Crop value, cost of production, etc.:									
Value	$6.58	$8.61	$7.84	$6.02	$5.18	$6.93	$10.22	.....	.....
Cost	6.56	6.09	4.75	5.55	7.17	14.61	11.50	.....	.....
Profit or loss	.02	2.52	3.09	.47	−1.99	− 7.68	− 1.28	.....	.....

[a] Only 1 plat up to 1911. [b] Only 1 plat after 1910.

The results of six years are available for study at this station. Three years have been years of good yields, one of light yield, and the other two of poor yields.

The best average yield for the six years from any one method of treatment is 14.9 bushels per acre from corn ground plowed in the spring before seeding to wheat. This is closely approached by summer tillage, with an average yield of 14.6 bushels per acre. The next highest yield, 13.3 bushels per acre, has been from corn ground plowed in the fall before seeding to wheat.

Disked corn ground has yielded an average of 11.2 bushels per acre. This yield is exceeded by nine-tenths of a bushel per acre by wheat following wheat on spring plowing.

Spring plowing has been productive of markedly heavier crops than fall plowing, irrespective of whether it was corn, wheat, or oat stubble that was plowed.

Furrowing with a lister and leaving the ground rough through the winter has given results practically the same as fall plowing similar stubble.

Subsoiling has been done at the expense of a decrease in the yields every year except the first, when its increase over similar stubble plowed at the same time was only 0.9 bushel per acre.

Green manuring has given about the same yields as land from which a crop was harvested. Of the different crops used for green manure rye has been the best and sweet clover the poorest, as judged by the yields obtained immediately following them.

When the cost of production is considered in connection with the yields obtained from different methods, the arrangement as presented shows a profit of $3.09 per acre from disked corn ground and $2.52 from spring plowing. Fall plowing and listed land both show merely nominal profits of a few cents per acre. Subsoiling and summer tillage show losses of $1.99 and $1.28, respectively. The high cost of green manure has increased the loss from it to $7.68 per acre. A more detailed presentation would show that the greater part of the profit from both spring and fall plowing was from corn ground.

HAYS FIELD STATION.

The soil on which the experimental work has been conducted at Hays, Kans., is a heavy silt loam. Penetration of water to the lower depths is slow. The very compact zone in the third foot offers marked resistance both to the downward passage of water and to the development of roots. While the evidence is not as complete as might be desired, it appears that the proportion of water that can be stored in the soil is comparatively high.

The results of five years are available from the Hays station, the crop of 1909 having been lost through a hail storm that destroyed it before maturity. Only two years have been productive of fair crops. The year 1914 has not been considered in computing averages. Indications are that under ordinary farm conditions yields might have

been fair, but soil blowing on the experimental plats delayed seeding until it was so late that the crop did not produce grain.

TABLE XV.— *Yields and cost of production of spring wheat by different methods at the Hays Field Station, 1908 to 1914, inclusive.*

Treatment and previous crops.	Number of plats averaged.	Yield per acre [1] (bushels).							
		1908	1909	1910	1911	1912	1913	1914	Average.
Fall plowed:									
Corn	1	3.9	[2] H	11.8	0	14.6	2.1	.....	6.5
Oats	3	4.7	H	12.7	0	15.4	1.8	.....	6.9
Wheat	1	4.5	H	9.6	0	15.2	.5	.....	6.0
Total or average	5	4.5	.....	11.9	.....	15.2	1.6	.....	6.6
Spring plowed:									
Corn	1	1.5	H	10.3	0	8.4	1.8	.....	4.4
Oats	1	2.2	H	11.6	0	12.8	1.8	.....	5.7
Wheat	1	1.2	H	7.6	0	11.6	1.0	.....	4.3
Total or average	3	1.6	.....	9.8	.....	10.9	1.5	.....	4.8
Listed: Wheat	1	5.2	H	15.0	0	11.8	1.5	.....	6.7
Subsoiled: Wheat	1	5.2	H	12.6	0	12.7	1.3	.....	6.4
Disked: Corn	1	3.7	H	10.6	0	16.2	4.3	.....	7.0
Summer tilled	2	4.2	H	11.3	2.2	15.2	7.3	.....	8.0
Average of all 13 plats	.....	3.8	.....	11.5	.3	13.8	2.6	.....	6.4

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.						Previous crop.	
	Fall plowed (5 plats).	Spring plowed (3 plats).	Disked (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Summer tilled (2 plats).	Corn (3 plats).	Small grain (8 plats).
Yields of grain:								
1908.....bushels..	4.5	1.6	3.7	5.2	5.2	4.2	3.0	4.0
1909.....do....	H	H	H	H	H	H	H	H
1910.....do....	11.9	9.8	10.6	15.0	12.6	11.3	10.9	11.8
1911.....do....	0	0	0	0	0	2.2	0	0
1912.....do....	15.2	10.9	16.2	11.8	12.7	15.2	13.1	13.8
1913.....do....	1.6	1.5	4.3	1.5	1.3	7.3	2.7	1.5
1914.....do....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	6.6	4.8	7.0	6.7	6.4	8.0	5.9	6.2
Crop value, cost of production, etc.:								
Value.....	$4.62	$3.36	$4.90	$4.69	$4.48	$5.60	.....	.....
Cost.....	6.56	6.09	4.75	5.55	7.17	11.50	.....	.....
Profit or loss.....	−1.94	−2.73	.15	− .86	−2.69	− 5.90	.....	.....

[1] Danger of soil blowing on experimental plats in 1914 delayed seeding until it was too late to mature grain
[2] H=Destroyed by hail.

The yields show very consistently an advantage of fall plowing over spring plowing, irrespective of the kind of stubble that is plowed. They also show wheat doing better after oats than after wheat, whether the stubble is plowed in the fall or in the spring.

Very small gains have attended both subsoiling and opening over winter with a lister instead of plowing.

Disking corn ground has been better than plowing it.

The best average results have been obtained from summer tillage. The gain of this method over disked corn ground, the next highest

yielding method, has been, however, only 1 bushel per acre. In one year of fair production, summer tillage for wheat was done at the expense of a distinct loss in yield as compared with nearly all other methods.

While the differences noted are of value as indicators, the yields are all so light and the average difference between the best and the poorest method so small as to make them perhaps of little practical moment. Considering the apparent impossibility of materially increasing yields by any method of tillage or management of the soil and considering a thing not shown in this study—the greater adaptation of winter wheat as shown by its higher and more certain yields and its greater response to tillage operations—it would appear that spring wheat has little or no place in the farm economy of this section.

The only method under trial that shows any profit is disked corn ground. In spite of its low average yield the cheapness of this preparation leaves it with the nominal profit of 15 cents per acre. The losses by other methods range from 86 cents for listing to $5.90 for summer tillage. There being less differences in yield than in cost of production, it follows that the least loss has been from the least expensive method.

GARDEN CITY FIELD STATION.

The work at the field station at Garden City, Kans., is on a high upland. The soil is a light silt loam. With the exception of the accumulated humus near the surface it is practically uniform to a depth of at least 15 feet. The development of roots is limited only by the depth to which water is available and the physiological character of the crop. The lighter character of the soil, however, makes it possible to store in each unit of it but a comparatively small proportion of water. This limited storage is not entirely overcome by the unlimited depth of soil. The results in storing water have been determined largely by the limited quantity of water available for storage. In no year, under any method practiced, has the soil been filled with water to as great a depth as it is possible for the crop to develop roots and to use available water.

The results of five years with spring wheat are available from this station, exclusive of 1913 when the crop was destroyed by hail on July 4. In 1911, which is included in the averages, the crop was a total failure from drought so extreme that it was not overcome by any method under trial.

The yields so far from any of the methods under trial have not been sufficient to indicate any possibility of the crop being a profitable one. Neither do the results attending any of the methods, which cover a wide range, indicate the possibility of sufficiently overcoming conditions by cultural methods to make it such. The work, however, has been of great value in the information it has

supplied that may find application in the growth of other crops better adapted to conditions. The benefit of the stored moisture accumulated in the soil by summer tillage or other methods is usually seen in the increased growth of straw, but never has it together with the rainfall been sufficient to mature the crop of grain it has promised. This indicates the advisability of growing feed crops which can be saved and utilized even though they do not mature grain.

TABLE XVI.— *Yields and cost of production of spring wheat by different methods at the Garden City Field Station, 1909 to 1914, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).						
		1909	1910	1911	1912	1913	1914	Averaged.
Fall plowed:								
Corn	1	2.2	9.2	0	7.3	[a] H	5.7	4.9
Oats	3	1.6	5.1	0	7.5	H	8.0	4.4
Wheat	2	3.4	5.0	0	3.9	H	3.9	3.2
Total or average	6	2.3	5.8	.....	6.3	.....	5.9	4.1
Spring plowed:								
Corn	1	4.0	3.5	0	8.2	H	[b]	3.9
Oats	1	2.5	2.7	0	10.0	H	3.1	3.7
Wheat	1	2.1	2.5	0	3.5	H	1.5	1.9
Total or average	3	2.9	2.9	.....	7.2	.....	2.3	3.1
Listed	1	3.2	5.7	0	11.0	H	5.8	5.1
Subsoiled	1	2.9	5.2	0	7.7	H	5.3	4.2
Disked: Corn	2	1.2	5.2	0	10.0	H	6.7	4.6
Green manured:								
Rye	1	1.4	5.8	0	8.8	H	[b]	[c] 4.0
Peas	1	0.9	4.8	0	7.5	H	[b]	[c] 3.3
Total or average	2	1.2	5.3	.....	8.2	.....	[b]	[c] 3.7
Summer tilled	3	5.6	7.6	0	8.8	H	7.9	6.0
Average of all 18 plats	.....	2.8	5.4	.....	7.8	.....	5.6	4.3

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Fall plowed (6 plats).	Spring plowed (3 plats).	Disked (2 plats).	Listed (1 plat).	Subsoiled (1 plat).	Green manured (2 plats).	Summer tilled (3 plats).	Corn (4 plats).	Small grain (9 plats).
Yields of grain:									
1909.....bushs..	2.3	2.9	1.2	3.2	2.9	1.2	5.6	2.1	2.5
1910.....do....	5.8	2.9	5.2	5.7	5.2	5.3	7.6	5.8	4.6
1911.....do....	0	0	0	0	0	0	0	0	0
1912.....do....	6.3	7.2	10.0	11.0	7.7	8.2	8.8	8.9	6.9
1913.....do....	H	H	H	H	H	H	H	H	H
1914.....do....	5.9	2.3	6.7	5.8	5.3	.....	7.9	6.2	4.9
Average.....	4.1	3.1	4.6	5.1	4.2	3.7	6.0	4.6	3.8
Crop value, cost of production, etc.:									
Value.....	$2.87	$2.17	$3.22	$3.57	$2.94	$2.59	$4.20	.....	.....
Cost.....	6.56	6.09	4.75	5.55	7.17	14.61	11.50	.....	.....
Loss.....	−3.69	−3.92	−1.53	−1.98	−4.23	−12.02	−7.30	.....	.....

[a] H=Destroyed by hail. [b] Crop blown out. [c] Average of 4 years only.

DALHART FIELD STATION.

The soil at the field station at Dalhart, Tex., is a sandy loam. In some respects it behaves like sand. In other respects it exhibits the characteristics of heavy clay soil. Its water-holding capacity is comparatively limited. The crops appear, however, to be able to utilize its water to the depth of a normal development.

TABLE XVII.— *Yields and cost of production of spring wheat by different methods at the Dalhart Field Station, 1909 to 1914, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).						
		1909	1910	1911	1912	1913	1914	Average.
Fall plowed:								
Corn	1	0	[1] H	0	[1] H	0	6.3	1.6
Oats	3	0	H	0	H	0	9.0	2.3
Wheat	1	4.0	H	0	H	0	9.0	3.3
Total or average	5	.8					8.1	2.2
Spring plowed:								
Corn	2	0	H	0	H	0	7.0	1.8
Oats	1	0	H	0	H	0		0
Wheat	1	0	H	0	H	0	7.8	2.0
Total or average	4						7.4	1.9
Listed: Wheat	1	8.8	H	0	H	0	12.9	5.4
Disked: Corn	3	0	H	0	H	0	7.0	1.8
Green manured:								
Rye	1	0	H	0	H	1.1		.3
Peas	1	0	H	0	H	1.0		.3
Total or average	2					1.1		.3
Summer tilled	2	9.1	H	0	H	.7	13.5	5.8
Average of all 16 plats		1.9				.2	9.5	2.9

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.						Previous crop.	
	Fall plowed (5 plats).	Spring plowed (3 plats).	Disked (3 plats).	Listed (1 plat).	Green manured (2 plats).	Summer tilled (2 plats).	Corn (6 plats).	Small grain (6 plats).
Yields of grain:								
1909.....bushels..	0.8	0	0	8.8	0	9.1	0	2.1
1910.....do....	H	H	H	H	H	H	H	H
1911.....do....	0	0	0	0	0	0	0	0
1912.....do....	H	H	H	H	H	H	H	H
1913.....do....	0	0	0	0	1.1	.7	0	0
1914.....do....	8.1	7.4	7.0	12.9	[2]	13.5	6.8	9.7
Average.....	2.2	1.9	1.8	5.4	.3	5.8	1.7	3.0
Crop value, cost of production, etc.:								
Value.....	$1.54	$1.33	$1.26	$3.78	$0.21	$4.06	.....	.....
Cost.....	6.56	6.09	4.75	5.55	14.61	11.50	.....	.....
Loss.....	−5.02	−4.76	−3.49	−1.77	−14.40	− 7.44	.....	.....

[1] H=Destroyed by hail.

[2] Discontinued.

Methods covering a wide range have been under trial in attempts to grow spring wheat each year since the station was started in 1908. Practically no success has attended these efforts. The crops have been lost by hail, drought, and soil blowing. In only three years of the six have any yields at all been obtained. In 1909, 9.1 bushels per acre were obtained from summer tillage and 8.8 bushels per acre from ground furrowed with a lister in the fall. In 1913 green manures and summer tillage produced yields not exceeding 1.1 bushels per acre. In 1914 yields were obtained from all methods except on those plats which were exposed to blowing from adjoining fields. The highest yield of spring wheat yet obtained on the station was 13.5 bushels on fallow in 1914.

While feed crops and late-planted crops have been grown here with success, the type of soil represented on the station farm is not adapted to the growth of small grains under the climatic conditions that exist.

AMARILLO FIELD STATION.

The soil at the field station at Amarillo, Tex., is a heavy clay silt. It is of the type locally known as "tight land" or "short-grass land." While the evidence is not as complete as could be desired, it appears that the storage of water and the development of the feeding roots of the crop are interfered with by a comparatively impervious layer of soil in the third foot. The soil above this, however, is competent to care for all the water that it has been possible to store, even under a system of alternate cropping and summer tillage.

The results of six years are available from this station. The year 1910 is not included; owing to a forced necessity for changing the location of the farm, the crops of that year were all grown on land uniform in its preparation.

Following corn, where the fall plowing is necessarily late, spring plowing has averaged better than fall and exactly the same as disked corn ground. Following both wheat and oats, fall plowing is done early, and has averaged better than spring plowing. Furrowing with a lister has averaged better than plowing. Subsoiling has resulted in exactly the same yields as plowing the same stubble at the same time without subsoiling.

Green manuring has been productive of practically the same yields as upon land from which a grain crop was harvested. Summer tillage has succeeded in raising the yields in a marked degree, but not enough to furnish compensation for the use of the method necessary to obtain them.

TABLE XVIII.—*Yields and cost of production of spring wheat by different methods at the Amarillo Field Station, 1908 to 1914, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).							
		1908	1909	[a]1910	1911	1912	1913	1914	Average.
Fall plowed:									
Corn	1	8.5	0	.....	5.7	1.3	0	11.7	4.5
Oats	2	13.5	0	.....	6.3	4.3	1.2	9.4	5.8
Wheat	[b]2	14.0	2.8	.....	10.0	8.5	1.5	11.9	8.1
Total or average	5	12.5	.7	.....	7.1	4.6	1.1	10.8	6.2
Spring plowed:									
Corn	1	8.0	0	.....	11.6	9.3	.5	10.2	6.6
Oats	1	5.3	0	.....	6.8	6.2	.2	3.3	3.6
Wheat	[c]1	16.2	0	.....	9.4	6.3	0	11.0	7.2
Total or average	3	11.4	0	.....	9.3	7.3	.2	8.2	6.1
Listed: Wheat	1	14.3	0	.....	12.9	4.7	1.5	11.0	7.4
Subsoiled: Wheat	1	16.2	4.0	.....	11.3	4.2	.8	12.3	8.1
Disked: Corn	1	8.3	0	.....	12.1	6.3	1.0	11.8	6.6
Green manured:									
Rye	1	14.2	4.3	.....	7.5	9.2	2.3	11.7	8.2
Peas	1	19.7	0	.....	11.4	8.7	2.5	10.7	8.8
Total or average	2	17.0	2.2	.....	9.5	9.0	2.4	11.2	8.6
Summer tilled	[d]6	16.3	10.0	.....	18.7	9.8	8.1	12.7	12.6
Average of all 19 plats	.....	13.3	2.1	.....	10.5	7.2	3.3	11.2	7.9

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Fall plowed (5 plats).	Spring plowed (3 plats).	Disked (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Green manured (2 plats).	Summer tilled (6 plats).	Corn (3 plats).	Small grain (8 plats).
Yields of grain:									
1908...bushels..	12.5	11.4	8.3	14.3	16.2	17.0	16.3	8.3	13.7
1909.....do....	.7	0	0	0	4.0	2.2	10.0	0	.9
1910[a].....do....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1911.....do....	7.1	9.3	12.1	12.9	11.3	9.5	18.7	9.8	9.0
1912.....do....	4.6	7.3	6.3	4.7	4.2	9.0	9.8	5.6	5.5
1913.....do....	1.1	.2	1.0	1.5	.8	2.4	8.1	.5	1.0
1914.....do....	10.8	8.2	11.8	11.0	12.3	11.2	12.7	11.2	10.0
Average.....	6.2	6.1	6.6	7.4	8.1	8.6	12.6	5.9	6.7
Crop value, cost of production, etc.:									
Value.....	$4.34	$4.27	$4.62	$5.18	$5.67	$6.02	$8.82	.....	.....
Cost.....	6.56	6.09	4.75	5.55	7.17	14.61	11.50	.....	.....
Loss.....	−2.22	−1.82	− .13	− .37	−1.50	− 8.59	− 2.68	.....	.....

[a] Location of station changed in 1910; records not used.
[b] One plat only to 1912.
[c] Two plats averaged to 1911.
[d] Only two plats were averaged up to 1912.

None of the methods under trial show the production of spring wheat at a profit. More profitable crops are produced from a group of crops not treated in this publication—the grain sorghums. It appears from the evidence at hand that the spring-sown small grains are not destined to occupy a place of major importance in the agriculture of this section.

GENERAL DISCUSSION OF RESULTS.

In the preceding pages data have been presented and briefly discussed separately for each station without reference to results at other stations. In the following pages some of the more important bearings and indications are considered from a more general standpoint.

To facilitate this study, Table XIX has been compiled, in which are brought together for each station the average yields as grouped for this study under different methods of preparation. The figures here given are taken from the last column of the tables as given for each station. The yield and cost of production data are also assembled in such a way as to show the profit or loss in dollars and cents per acre for the average crop for each method for which it has been computed at each station.

TABLE XIX.—*Comparison of the average yields and profit or loss on the production of spring wheat, by different methods of tillage at 14 stations in the Great Plains area.*

Statement of data.	Number of years averaged.	Methods of tillage.						
		Fall plowed.	Spring plowed.	Listed.	Subsoiled.	Disked.	Green manured.	Summer tilled.
1	2	3	4	5	6	7	8	9
Yields per acre (bushels):[1]								
Judith Basin	5	22.1	21.7	21.7	22.8	22.5	20.4	20.8
Huntley	2	20.0	19.5	18.0	16.0	22.4	22.3	25.9
Williston	5	15.3	15.9	.....	.....	16.2	18.6	20.2
Dickinson	6	20.1	19.8	.....	.....	23.3	22.2	27.5
Edgeley	8	15.3	15.5	.....	.....	17.7	16.7	17.9
Hettinger	3	13.4	13.7	.....	.....	15.7	14.6	20.4
Belle Fourche	6	7.0	6.5	7.5	6.7	8.8	9.2	11.5
Scottsbluff	3	9.6	11.5	9.4	9.4	14.0	13.3	19.9
North Platte	8	11.6	10.6	.....	.....	10.4	.....	16.8
Akron	6	9.4	12.3	8.6	7.4	11.2	9.9	14.6
Hays	6	6.6	4.8	6.7	6.4	7.0	.....	8.0
Garden City	5	4.1	3.1	5.1	4.2	4.6	3.7	6.0
Dalhart	4	2.2	1.9	5.4	.....	1.8	.3	5.8
Amarillo	6	6.2	6.1	7.4	8.1	6.6	8.6	12.6
Average[1]	.....	11.6	11.6	10.0	10.1	13.0	13.3	16.2
Profit or loss (−) per acre:								
Judith Basin	5	$8.91	$9.10	$9.64	$8.79	$11.00	−$0.33	$3.06
Huntley	2	7.44	7.56	7.05	4.03	10.93	1.00	6.63
Williston	5	4.15	5.04	.....	.....	6.59	− 1.59	2.64
Dickinson	6	7.51	7.77	.....	.....	11.56	.93	7.75
Edgeley	8	4.15	4.76	.....	.....	7.64	− 2.92	1.03
Hettinger	3	2.82	3.50	.....	.....	6.24	− 4.39	2.78
Belle Fourche	6	−1.66	−1.54	− .30	−2.48	1.41	− 7.17	−3.45
Scottsbluff	3	.16	1.96	1.03	− .59	5.05	− 5.30	2.43
North Platte	8	1.56	1.33	.....	.....	2.53	.....	.26
Akron	6	.02	2.52	.47	−1.99	3.09	− 7.68	−1.28
Hays	5	−1.94	−2.73	− .86	−2.69	.15	.....	−5.90
Garden City	4	−3.69	−3.90	−1.98	−4.23	−1.53	−12.02	−7.30
Dalhart	6	−5.02	−4.76	−1.77	.....	−3.49	−14.40	−7.44
Amarillo	6	−2.22	−1.82	− .37	−1.50	− .13	− 8.59	−2.68

[1] The averages of columns 3, 4, 7, and 9 are strictly comparable with each other; columns 5 and 6 approximately so; column 8 is not comparable with any other.

Table XIX shows a rather natural division of the stations into two groups. At the 10 more northern stations spring wheat has been grown at a profit by at least one method. At Belle Fourche the only profit was $1.41, from disked corn ground. At the 4 more southern stations the only profit realized from any method has been 15 cents an acre from disked corn ground at Hays.

When tests on fall-plowed ground following corn, oats, and wheat are averaged together and compared with spring plowing following the same crops, the averages of the two methods at the 14 stations are the same for the years averaged. At only 3 stations—Scottsbluff, Akron, and Hays—are the average differences greater than 1 bushel per acre. At Hays the advantage is with fall plowing and at the other 2 stations with spring plowing. At most stations the average difference is too low to receive much consideration. The advantage of one over the other depends chiefly upon the season, as is shown in the detailed tables. The data indicate the importance of understanding the general principles that govern the observed seasonal variations and the importance of adjusting this work to the general economy of the farm organization. This subject is too broad to be considered here, and a separate publication dealing with it in detail is in preparation. The small difference in cost of the two methods makes relative profits and losses from them follow closely the differences in yields.

Disked corn ground has given consistently high yields. This, together with the low cost of this preparation for wheat, has resulted in its uniform showing of the greatest profit per acre at those stations where it has been possible to raise wheat at a profit and the least loss at those stations where wheat has been raised only at a loss. The only exception to this is at Dalhart, Tex., where yields have been so low as to be of little practical moment. The realization of these profits depends, of course, upon the successful growth of corn as a general farm crop in competition with other crops.

It should be borne in mind that at all stations disking corn ground as a preparation for all small grain crops has been done upon corn land kept free from weeds. If weeds were allowed to develop in the corn similar results should not be expected. To the extent that the weeds developed or were unhindered in their growth, the corn ground would approach a grain stubble in the condition of the seed bed. If the weeds matured seed, further damage might be done by their growth in the succeeding crop. Where moisture is the limiting factor, weed growth is decidedly detrimental.

Subsoiling, as compared with similar wheat stubble fall plowed without subsoiling, has been of doubtful utility as a means of increasing yields. As a means of overcoming drought it is without value. Only at Judith Basin and Scottsbluff has it been able to

account for an increase of more than 1 bushel per acre. At Judith Basin the increase has been 1.9 bushels and at Scottsbluff 2.5 bushels. This evidence from eight stations, some of which have records for study covering eight years, together with the evidence at hand but not here reported of other work on depth of plowing, which includes deep tilling and dynamiting, would seem to be conclusive that the nature of the Plains and the trend of their agriculture are not to be changed by the simple expedient of working them to a greater depth than is reached by the ordinary plow and equipment.

Listing wheat stubble instead of plowing it in the fall has resulted in a small increase of yield at seven of the eight stations where it has been tried. At Amarillo it has increased the yields in the years of heaviest wheat production, but it shows on the average a loss of 0.6 bushel per acre at this station. As it is a somewhat cheaper method of preparation than fall plowing, it has consequently been a more profitable one.

Except at the Judith Basin and Akron stations, summer tillage has given the highest average yields of any method under trial. At Akron the yield on summer tillage has been exceeded by that on spring-plowed corn ground by 0.3 bushel per acre. The reason for the departure at the Judith Basin station from the general rule is discussed under that station. For the whole 14 stations under study the average increase in yield over disked corn ground has been 3.1 bushels per acre. Summer tillage requires the use of the land two years to produce a crop and requires an extra amount of cultivation to keep it free from weeds in the fallow year. It consequently has the highest acre cost of any method under trial except that of green manuring. A study of the relative profits and losses from different methods, as given in Table XIX, shows that the increase in cost of production by summer tillage has been relatively greater than the increase in yields resulting from it. With one or two exceptions the highest yields have been obtained by this method. It has not at any station been the most profitable when a profit was realized nor has it been the source of the least loss where wheat has been raised at a loss. At eight stations it shows a profit, but a smaller one than was realized from some other method or methods. At three other stations it has resulted in a loss while some other methods have resulted in profit. At the remaining three stations its practice has increased the loss attending the use of less expensive methods.

Green manuring is the most expensive method under trial. It resembles a fallow in that it requires the use of the land for two years for the production of one harvested crop, with the added expense of seed and seeding. There is a saving in cultivation during the spring while the crop is growing, but this is offset by the necessity of plowing to turn the crop under and is not sufficient to make up for the cost

of seed and seeding. Yields have not been commensurate with the increased cost of producing them. At no station have the average yields following any green manure exceeded those from summer tillage. At Huntley and Dickinson, the two stations having the highest average yields, small profits have been realized from this method in spite of its high cost. At the 10 other stations at which it has been under trial the result has been a monetary loss, both actually and in comparison with other methods.

It is hardly fair to charge the whole expense of green manuring to the one crop that immediately follows it, as is here done. It should have a cumulative effect in building up the soil or remedying its deficiency in organic matter. The available evidence is that on normal soils in the Great Plains, at least in the first years of the work, little effect is shown on other than the first crop. This effect is that of a fallow to the extent that the green manure approaches a fallow in the storage of water during the period after the crop is plowed under.

At different times and in different sections certain methods have been exploited as the solution of the problems of dry farming. Each of these systems may have merit, but any and all fall far short of a panacea under all conditions. The observations and investigations that have developed these systems, or upon which the advocacy of special methods have been founded, have been altogether too limited both in geographic extent and in range of time. There is always, too, the temptation to magnify the importance of those single years which may be exceptional, but whose results point strongly in the desired direction, losing sight of the fact that it is the average of a long series of years upon which the agricultural organization and practices of a section are and must be based.

The scope of the work in hand is broad enough, both in length of time and in geographic distribution, to overcome these objections. One fact conclusively shown is that cultivation is not an unfailing solution of the problem of drought. It will doubtless alleviate it to some extent, but can never fully overcome it. Some methods have shown consistent merit under some soil conditions. The same system when transplanted to some other environment may show little or no merit. With the exception of one year at one station the greatest difference in yield between the supposedly good and the supposedly poor method has been in the good years rather than the bad years. This shows that good systems have more efficacy in augmenting the results obtained in a good year than in overcoming the conditions of a very unfavorable year.

A study of the data given in the tables will show that at some stations no material difference has resulted from the various methods of tillage used in preparing the soil for spring wheat.

On shallow soil, where the development of roots and the recovery of water is limited by underlying shale, or on shallow soils underlain by gravel impervious to plant roots, one can not expect to get any material benefit from systems of tillage calculated to increase the storage of water in the soil. The shallowness of the soil will of itself limit the amount of water that can be stored in it. It may be that one heavy rain or rainy period will be sufficient to fill such a soil completely. After it has been filled to its carrying capacity it is obvious that no amount of cultivation will increase its water content. Crops grown on such soils are dependent upon seasonal rainfall.

The soils upon which these investigations have been made are in the main fertile. In most cases they have been but recently broken from the native sod and in no case has the fertility been dissipated by long-continued cropping. Unless some abnormal factor enters in, such as hail or injurious insects, the yield obtained is largely determined by the available water. Since the water available to the crop on shallow soils can not be materially increased by cultivation, and since on these soils water is the chief limiting factor, it is unreasonable to expect much increase in yield from one method of tillage over another.

On uniform soils of sufficient depth to allow the accumulation of a surplus of water, wider variations in yields are to be expected from the various methods, under climatic conditions favorable to the storage of water. Such results have been obtained at several of the stations. The differences in yields, however, from different methods of tillage, have not been the same from year to year, even on the most responsive soils, but have varied with the climatic conditions. In some years comparatively wide differences are obtained. In another year the climatic conditions may be unfavorable and little or no differences in yield are shown. The rainfall might be so distributed that it could not be accumulated in the soil by one method more than by another. If only light showers came, or dry weather prevailed during the practice of some system calculated to accumulate water in the soil, it is obvious that little or no water would be stored. If the rains came later in sufficient amount and falling slowly enough to avoid run-off, the soils under all methods would be filled with water, which would tend to equalize the resulting yields. If, on the other hand, little or no rain came and none had been stored, the results would be equalized in failure. It must be borne in mind that cultivation of itself does not accumulate the water in the soil. There must first be rain. The cultivation can assist only in getting the water into the soil and in preventing its loss through weeds, by run-off, or by vaporization and loss through shrinkage cracks.

At some stations the yields have been so nearly practical failures that it is evident that the growing of spring wheat is not a profitable practice. At other stations one or two crops show a profit, while the remaining ones are practical failures. They indicate that the farmer may not find spring wheat profitable on the average even though some years show a profit. That a certain locality is not favorable to the growing of spring wheat does not mean that it is not a farming section. It simply indicates that soil and climatic conditions are not favorable to the production of this crop. Other crops may find their most favorable environment at such a place. Only one crop is herein discussed. At every station some crops have been grown that have given good returns. At the southern stations, for example, the grain sorghums have done well and should be considered the main crops.

Where work has been carried on for several years with no material difference in yield obtained from the various methods, it indicates that more freedom may be used by the farmer in planning his operations. If spring plowing, fall plowing, or disking after some intertilled crop gives practically the same yields, the rational thing to do is to take advantage of this fact. It is desirable to plow when it can be done most economically for men and teams. If the cropping system includes intertilled crops and disking is as effective and can be done at less labor cost, it is advisable to disk the land to prepare for wheat. Unless there is a gain from some certain method of tillage or crop sequence, one should adjust the work from the standpoint of economical operation. The farmer can then give his thought to procuring better seed, keeping ahead with his work, and preventing the growth of weeds.

CONCLUSIONS.

These conclusions apply only to the yields of spring wheat as affected by the cropping and cultivation of the one year immediately preceding their growth.

(1) Some seasons are so unfavorable as to result in failure of the spring-wheat crop without regard to the cultural methods under investigation. Extremely unfavorable climatic conditions can not be overcome by cultural methods.

(2) It is only in those seasons when the rainfall deficit is so small that it can be overcome by moisture stored in the soil that the cultural methods under investigation have shown important effects upon yields.

(3) When the differences in value of the yields are less than the differences in cost of production, then cost becomes the determining factor.

(4) Some soils, even in the regions of profitable spring-wheat production, show little response to cultural methods.

(5) Reducing the cost of production has in most cases in these investigations proved a more important factor in determining profits than increasing yields by cultural methods.

(6) Northern Colorado and Kansas seem from these investigations to be the southern limit of profitable spring-wheat production on the Great Plains. This limitation does not apply to winter wheat and other crops under investigation.

(7) Disked corn ground has given consistently high yields. This, together with the low cost of preparation, has resulted in its showing the highest average profit or lowest average loss of any of the methods tried at all of the fourteen stations except one. These profits are based on the assumption that the corn crop was so utilized as to pay for the cost of its production. (If the corn crop was grown at a loss, this loss should be deducted from the profits on the wheat crop following it.)

(8) Furrowing with a lister and leaving the surface ridged through the winter has resulted in a small increase in yield over plowing at seven of the eight stations where it has been tried. As it is a somewhat cheaper method of preparation than plowing, it has consequently been more profitable.

(9) The average difference in the yields of spring wheat following fall plowing and spring plowing are very small. At most stations the advantage of one over the other depends upon the season.

(10) Subsoiling has been of doubtful utility as a means of increasing yields. As a means of overcoming drought it is without value.

(11) Summer tillage without crop has given the highest average yields of any method under trial at 12 of the 14 stations. However, on account of its high cost, due to extra labor and alternate-year cropping, it has not been the most profitable practice.

(12) The most expensive method under trial is green manuring. It has produced less profit or greater loss than any other method under investigation.

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